FUTURE TECHNOLOGY IN THE CALIFORNIA DESERT

Final Report

August 1978

Prepared for:

California Desert Planning Program
Bureau of Land Management
Riverside, California

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CONTENTS

ILLUSTRATIONS

LIST OF TABLES

I SUMMARY

The expected technological developments of the next 20 years are not likely to have serious effects on traditional uses of land in the California Desert Conservation Area (CDCA). Improvements in management techniques, which are included in the broad definition of new technology, are more likely to have significance for the CDCA than are developments in hard technology.

For this survey of future trends in technology, technologies in the following eight areas were identified as having the most significance for the desert: water, energy, agriculture, recreation, materials, communications and space, military activities, and transportation. Capsule summaries of findings for each of the areas follow.

Water

The desert area will not acquire major sources of new water, nor will it lose those that it has. It will be hard-pressed, however--even by using conservation and recycling methods, and groundwater--to provide for municipal and industrial needs for expected growth. The fate of the northern desert was determined when the Los Angeles Department of Water and Power took water that might have been used for desert irrigation from the Owens Valley. Likewise, the fate of the southern desert was determined when Colorado River water was brought into the Imperial and Coachella valleys.

Energy

Geothermal energy will prove to be a significant desert development, but it will support little indigenous industry. Solar energy in various forms will pose both a national opportunity but a regional threat to the desert; however, this will be the case only if water is made available or solar cell technology is developed.

Agriculture

Agriculture can expand only by using water more efficiently and by developing plants that can grow in salty and sandy soils and in hot summer temperatures, or that can be productive with little water. Genetic improvements of existing plants and animals raised in the desert and the introduction of new species of plants will probably constitute the most significant occurrences.

Recreation

Continued improvement in off-road vehicles suggest that their increased use will pose problems in managing desert recreation. Major new technological areas for desert recreation include personal flying equipment (e.g.,

motorized hang gliders, gyrocopters, and parafoils); better camping and backpacking equipment, including clothing and shelters; and new desert institutes that emphasize the natural attractiveness of the desert through education, research, and tourism.

Materials

Energy conservation technology will use more desert minerals, for existing purposes. In addition, expanded use of glass fiber composite materials, lithium for electric automobile batteries, lithium and rare earths for lasers and electrooptical devices, and glass for fiber optics could pose major new requirements for minerals found in the desert.

Communications and Space

Space activities will have little direct impact on the desert; however, satellites for communications, navigation, and remote sensing will remove some constraints to using the desert, and will provide excellent means of observation for land-use management.

Military Activities

The military presence in the desert will remain at about its present level. Because individuals and communities will increasingly encroach on military reservations, land-use planners should consider whether buffer areas are necessary. Increasing military and civilian air traffic is now causing dangerous airspace congestion and will require a comprehensive and coordinated air traffic control system for the desert region. Large military desert reservations have provided some degree of environmental protection by excluding developers and the public.

Transportation

Few, if any, technological innovations in transportation will produce major impacts on the desert; possible exceptions are electrification of one or more major rail lines through the CDCA and the continuing shift of general aviation from crowded metropolitan airports to rural airstrips in the CDCA.

Interactions

No area of technology can be neatly defined or considered in isolation. Because most technologies or management techniques span two or more of the areas considered here, they have multiple significance. For example, future water technology will have a significant impact on the pact of energy and agricultural developments; the process can work the other way as well: future energy developments are likely to increase demand for water. Figure 1 presents a matrix of technological developments, showing the one or two areas of desert activities that each will affect most. Further descriptions of these developments can be found in the main text under at least one of the areas indicated.

WATER	ENERGY	AGRICULTURE	RECREATION	MATERIALS	COMMUNICATIONS AND SPACE	MILITARY	TRANSPORTATION
• CONSERVATION • RECYCLING • WEATHER MODIFICATION							
• COMPETITION FOR COLORADO RIVER WATER • PUMP POWER	• NUCLEAR • CENTRAL SOLAR • GEOTHERMAL						
• DRIP IRRIGATION • OROUGHT-RESISTANT CROPS • OESALINATION	• GEOTHERMAL CROP DRYING • BIOMASS PRODUCTION • WIND POWEREO IRRIGATION	• SPECIALIZED DESERT CROPS					
• ARTIFICIAL LAKES	• EFFICIENT POWER SOURCES		• DESERT INSTITUTES				
• EVAPORATION BARRIERS	• LITHIUM BATTERIES • SOLAR CELLS • INSULATION (GLASS FIBER)	• CONTROLLED ENVIRONMENT AGRICULTURE	• BETTER CAMPING AND BACK-PACKING EOUIPMENT	• WASTE DISPOSAL			
	• EFFICIENT POWER SOURCES	• LAND USE MANAGEMENT	• COMMUNICATIONS ANO NAVIGATION FOR OUTOOOR RECREATION	• MINERALS • EXPLORATION • FIBER OPTICS	• TELEPHONE SYSTEMS		
	• SOLAR HEATING AND COOLING OF BUILDINGS • GEOTHERMAL RESOURCES		• COMPETITION FOR SPACE	• LASERS • ELECTRO-OPTIC OEVICES	• SURVEILLANCE • NAVIGATION	• ENVIRONMENTAL PROTECTION • MODERN WARFARE TRAINING • WEAPON TESTING	
	• ELECTRIFICATION OF RAILWAYS	• RUBBER-PRODUCING CROPS	• PERSONALIZEO FLYING EOUIPMENT • RECREATIONAL VEHICLES • BATTERIES	• GLASS FIBERS • SYNTHETIC GREASES	• SPACE SHUTTLE LANDINGS • NAVIGATION	• AIRSPACE CONGESTION	• AIRFIELD RELOCATION

FIGURE 1. MATRIX OF SIGNIFICANT TECHNOLOGICAL DEVELOPMENTS THAT COULD AFFECT THE CALIFORNIA DESERT

Land Use Implications

Because the expected importance of technological developments for the desert is, in aggregate, small and because the confidence in any one prediction is low, conclusions about their land use implications for the Bureau of Land Management are highly speculative. Table 1 presents illustrative issues that might arise (and in some cases that have already arisen) because of technological factors and that must therefore be considered as contingencies in preparing a plan for land use in the CDCA.

Table 1

POTENTIAL LAND USE POLICY
IMPLICATIONS OF NEW TECHNOLOGY

Water	Growth limitation strategies Canals, pipelines, or wells on public land Interbasin water transfers Expansion of irrigated land
Energy	Leasing of land for geothermal resource development Solar arrays on public lands Additional rights-of-way for transmission lines
Agriculture	Leasing of land for arid land crops Leasing of land for grazing
Recreation	Control of access to public lands - Number of visitor-days - Restrictions on vehicles Limitation of damage to cultural and geologic resources Encouragement of educational and research activities
Materials	Exploration of public lands Leasing of mineral resource
Communications and Space	Indirect
Military	Creation of buffer zones Control of recreational and tourist encroachment
Transportation	Leasing of rights-of-way

II INTRODUCTION

SRI International has prepared this report for the U.S. Department of the Interior, Bureau of Land Management (BLM), to provide information for use in the preparation of a land management plan for the California Desert Conservation Area (CDCA). The results of one of four tasks in the California Socioeconomic Study prepared by SRI International are presented.

Study Objective

This task has identified potential future technologies that could significantly affect the CDCA during the next 20 years in 8 areas of enterprise that are, in one way or another, currently important. The eight, chosen in consultation with the BLM, are: water, energy, agriculture, recreation, materials, communications and space, military, and transportation. The task also considers major impacts associated with new technologies likely before 2000. This report reviews what authorities on new technologies, especially those that pertain to the desert area, believe will be implemented in the desert area before 2000, as well as other technologocal possibilities that could occur and might have significant effect during the 20-year period.

The Scope of the Study--the CDCA

Figure 2 shows the CDCA, the area of primary concern here: the area for implementing new technologies. It includes all or portions of eight California counties. Also important are activities in adjacent areas (e.g., passenger and freight traffic going into the Los Angeles, Long Beach, and San Diego metropolitan areas through, over, or under the CDCA). New technologies designed to meet these kinds of exogenous demands, when they clearly could affect the desert area, were also examined.

Background

Technology is the implementation of a mature science. It sometimes satisfies an existing need; sometimes it creates its own demand. It is preceded by scientific development; it requires various implementation steps to bring it into being, interest groups to promote it, and consumers to use the products or services it engenders or improves. Existing institutions support or slow technological development, and eventually new institutions will evolve to regulate it. Thus, a search for new technologies that may have impact on the CDCA includes the following considerations:

- How do past, present, and future resources and land uses of the desert relate to technological development?

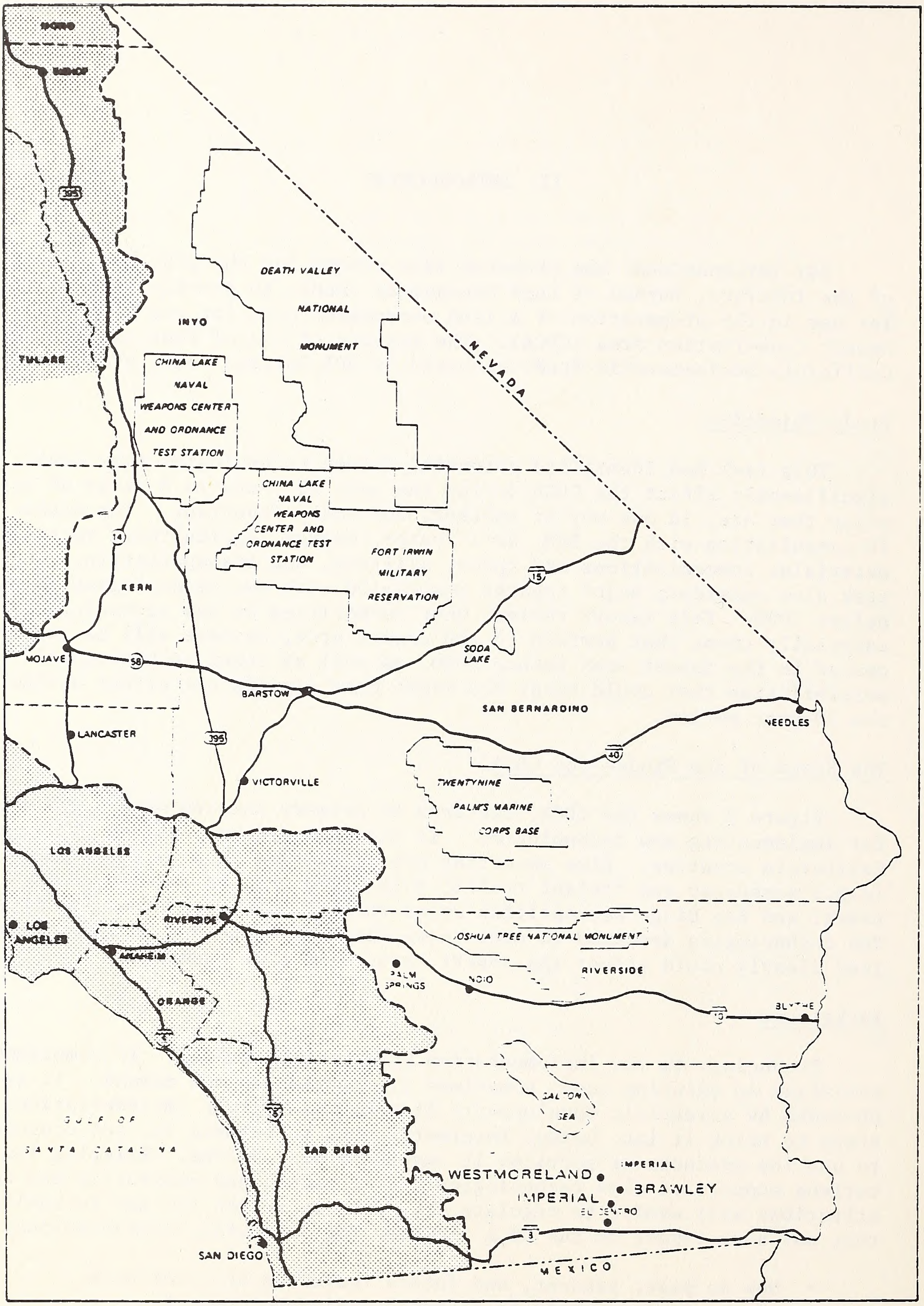

FIGURE 2. CALIFORNIA DESERT CONSERVATION AREA

- What are the potentials of the desert if a new technology is available?
- What scientific inquiries are taking place that are related to the desert?
- What scientific inquiries are taking place that could apply to the desert, although they are not directly related to it?
- What currently available technologies are transferable to the desert?
- What are the interests, organizations, and institutions that will facilitate or restrain those activities in the desert that require technological development?

Usually technology reaches maturity through research, development, and demonstration; industrialization; and commercialization. In the last two stages society begins to accept a new technology and make institutional and other adjustments to it. It is in these stages that most of the major impacts occur. However, some impacts do not occur until well after commercialization (e.g., the impacts of airborne effluents from automobiles were not widely noticed until autos were well established as the dominant mode of personal transportation in the United States.

Questions directed toward the various areas of technology of concern here included:

- How mature is the technology; where does it stand in the R&D, demonstration, industrialization, commercialization chain?
- How mature is society with respect to the technology; how will public policy effect the development and control of the technology and its impacts?
- What are the perceived needs and possible alternative ways--technological or otherwise--of fulfilling those needs?
- For those technologies that have not matured, what are the prospects for achieving maturity in terms of the stakeholders and decision makers?
- What are the potential impacts of future technologies and how are the parties-at-interest likely to be concerned or affected by these consequences?

The following items, which relate to water recovery, transportation, and use, and their potential consequences for the CDCA, are examples of the many issues surrounding the future direction of technology:

- Enforcement of the Reclamation Act's 160-acre limitation.
- Completion of the Central Arizona Project, with the guaranteed minimum of 4.4 million acre-feet allocation of Colorado River water to California.

- Construction of a peripheral canal to facilitate diversion of Sacramento River water to Southern California.
- Federal-state agreements on release of federal water to maintain salinity limits in the western Sacramento-San Joaquin Delta.
- Future droughts in the Upper Colorado River Basin and Northern California.
- Augmentation of Colorado River and Northern California river flows by weather modification.
- Energy development projects in the Colorado River Basin.
- Increased groundwater use in California and the Colorado River Basin.
- Increasing salinity in the Salton Sea.
- Disposal of geothermal brines in the Salton Sea.
- Reinjection of Salton Sea water to maintain or enhance energy production in geothermal wells.
- More efficient use of water in agriculture.
- Reduction of water losses in storage and distribution.
- Development of drought-resistant plant species.
- Development of desalting and waste water reuse technology.

A Note on Futures Research

These technology forecasts fit loosely within the discipline called "futures research," which includes most studies about the future, except those concerned with the immediate future. The term implies many different plausible and possible alternative futures, rather than a single, determinate image of the future. To a large extent, futures research aims to identify and clarify major uncertainties about the future--in this case, about technologies that may reach commercialization and affect the CDCA before the year 2000. In most futures research, context is considered important. For this study, context includes the complex of social, economic, environmental, and technological factors that surround, contribute to, and sometimes block the development, industrialization, and commercialization of new technology in the CDCA.

Most futures research approaches context and these kinds of technological forecasts in one of two ways. The one used here employs expert opinion to arrive at consensus forecasts about the future. Differences of opinion about future contexts are allowed, but the emphasis falls on reaching a consensus. the second method generally ignores consensus; rather, it defines a set of different socioeconomic contexts called alternative futures scenarios and then makes forecasts for each scenario.

In this study, for the sake of simplicity and to limit the scope, a single social context has been assumed. Of course, plausible alternative

contexts exist in which other technologies may become prominent or in which some of those identified here as having small impact could become quite important. However, we have not concerned ourselves with these types of alternatives: they are the focus for a more elaborate study. On the whole, the forecasts in this task represent the best judgment of experts knowledgeable about these technologies and about the CDCA (or similar desert areas).

Methodology

The approach we chose for forecasting technology combines the development of a single future context with a poll of experts in each of the eight areas of technology. The scenario selected is a median image of the future to the year 2000. It has been adapted from scenarios of the U.S. future created for public and private agencies, although it resembles no particular scenario. For the most part, it assumes moderate economic growth, slowed population growth, persistent but not insurmountable or devastating energy problems during the next decade, and the beginnings of a transition to a postpetroleum economy during the 1990s. We assume that present social values and public policies persist. In interviewing experts, on the desert, we let them identify the policy and other factors they saw as consistent with particular technologies (if such factors existed).

To acquire expert opinion, we used a methodology similar to journalistic investigative reporting. The experts interviewed thus not only have specialized technical knowledge but also participate in developing and implementing the technology and in establishing input for policy decisions. The expert opinions acquired in unstructured and open-ended interview were combined with information gained from literature search and from knowledge obtained from the other tasks in the study to produce a comprehensive image of evolving trends.

All methods of forecasting the future are, however, subject to limitations. We do not understand how social forces interact in complex and subtle ways to produce social and technological change. We cannot anticipate events like a devastating war or a new religious movement that may completely shift the direction that society now seems to be taking. We cannot determine how synergisms between different technologies may lead to entirely new developments. Other methods sometimes used for technology forecasting deal with these weaknesses in different ways;* these methods include:

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*See, for example, Martino, J. P., Technological Forecasting for Decision-making (New York: American Elsevier Publishing Co., Inc., 1972).

- Extrapolation of identified trends
- Analogies with historical experience or similar situations
- Discovery of underlying "laws" in observation of social organizations
- Normative assumptions of the nature of man and social interactions
- Thinking that incorporates concepts of human needs and the formation of social values
- Development of formal simulation models of technology development and implementation.

Some of these approaches work in certain situations and fail in others; the problem is in knowing which method is going to work. We have also drawn on other studies that employ these and other methods, and that have surveyed the same or similar questions. For most areas, however, few if any formal forecasts of future technology were available. Therefore, interviewing experts and analyzing their responses proved the most fruitful way to construct consistent forecasts of future technology.

For the most part, we have assigned neither probability estimates nor quantitative impact measures to the technologies of interests. Impact factors associated with most technologies that our respondents identified as highly probable before 2000 were noted when possible. The timing of commercialization was, on the other hand, a major question, and we have incorporated the experts' expectations of timing when they were available. Because of the long lead times needed to plan, finance, build, and bring into operation large, complex technological systems, most of these were indicated to be more likely in the 1990s than before. Similarly, the commercial possibilities and impacts of technologies still in the R&D stage were frequently forecast to take place after the year 2000; however, we have noted those technologies that experts indicated were most important, if timing estimates prove conservative.

Finally, we cannot ensure that these forecasts encompass all possibilities, or even all significant technologies. Almost certainly R&D surprises will occur, along with major changes in public or private policy that brings certain technology on line with unexpected speed, as well as such major surprises in context as changes in weather patterns that could affect desert agriculture, water resource exploitation, and energy development. Because it is impossible to plan for all contingencies, a prudent plan will attempt to allow for those changes that are foreseeable, based on the best knowledge available today. This report synopsizes existing knowledge concerning technologies that are likely to affect the desert.

The Socioeconomic Context, 1978-2000

Within the next 20 years our society, now characterized by high energy consumption, will change to one that conserves energy. The American socioeconomic milieu in the year 2000 will be an uncomfortable but working

union of two approaches to a conservation ethic: one is voluntary simplicity* and the other is forced simplicity. Each tolerates the other's values and life styles, and the net effect is a growing but by no means pervasive simplification or scaling-down of some kinds of technology. Technology will have been systematically applied to conservation. Many conventional technologies will have become highly refined and new technologies will have been introduced as well, but the overall pace of technological innovation will be slower than during the previous quarter century. In addition, some social and institutional adjustments will have been made possible in the name of the common goal of conservation.

In the year 2000, the United States will have entered an era of slower population growth. A high proportion of the nation's capital will go into modernizing production equipment. Jobs will be plentiful, but real earning power will have grown more slowly than in the 1960s and 1970s because of continued inflation and devaluation of the dollar versus foreign currency. However, as new technology and production equipment are introduced, the real earning power will seem to be rising again. U.S. goods will be priced competitively in the world market. The values of low consumption craftsmanship and durability introduced by the voluntary simplicity movement, together with new technology and production equipment, will bring back the American reputation for quality goods in the world market.

The accommodations between the two approaches to achieve a conservation ethic will have produced a political system that features more central planning and more resource allocation by administration. At the same time, however, the more openness and responsiveness to the public will occur at the level of implementation. Environmental goals and practice will have responded similarly. High environmental quality will be sought, but not at any price. Tradeoffs can and should be made in certain circumstances in order to solve and not stall problems. Land use planning will reflect acceptance of centralized planning, together with public involvement in implementation. Under legislative mandates, the federal administration and its line agencies will establish goals and guidelines whose implementation is uniquely adapted by local agencies. The major social urge is to pick up the pieces of a problem-ridden energy system and to rebuild it. The government will give necessary direction for this reconstruction without stifling initiative.

When institutions prove unable or unwilling to adjust to the situation they will in effect be ignored and replaced, if necessary. Big government, big business, and big labor will still be present, but they will be less monolithic and more responsive to their local constituencies. They will also be increasingly challenged by smaller organizations as the people experiment with new institutional forms.

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*Elgin, D. and Mitchell, A., "Voluntary Simplicity," Co-Evolution Quarterly 14: 4-19 (Summer 1977).

The populace will combine to achieve the common goal of conservation. Cooperation is observed to disappear when crises have passed, and often mistakes are repeated in rebuilding.

III WATER RESOURCES AND TECHNOLOGY

Introduction

Water is the key to permanent development in the California Desert. "Permanence" is relative, but development is not permanent unless investors can amortize--in at least a generation--their investment in nontransferrable resources. The length of time is important because both renewable and nonrenewable water resources are involved. Renewable water resources can support continuous activity, whereas nonrenewable resources have limited economic lifetimes. The Imperial and Coachella Valleys exemplify the impact of a cheap, reliable, renewable water supply that has transformed a desert region into a major agricultural supplier.

Sources of Water

Several sources of water could be economically applied to the California Desert:

- Natural precipitation that falls as rain on the desert floor or that builds up as snowpack in the high elevations of the eastern Sierras. No short-term climate changes are anticipated but there will, in the near future, be greater variations in weather conditions.* Even though they bring more water to the desert, such conditions will probably do more harm than good because of flooding and erosion by runoff.
- Groundwater that results from percolation of precipitation or runoff into the permeable subsurface formations, or that has been deposited in ancient times and essentially sealed off from the present hydrologic cycle by intervening geologic processes.

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*Most present observers use the post-World War II period as the basis for "normal climate." However, McQuigg,et al. (1973) and Temkin (1977) have shown that the 16 year period from 1957 to 1973 was marked by unusual weather when compared with "normal" weather over centuries. In the wheat belt states this may be called the "high-yield era." All years (with one exception) had normal or above-normal rainfall and normal or below-normal temperature. There is no physical reason to expect that this abnormal trend will continue. Indeed, parts of these states have recently experienced 2 to 3 years of drought.

- Water imported from the Colorado River Basin or from Northern California.

The water must be of adequate quality to be of use in given applications. Water that is high in dissolved salts, especially those of toxic materials, cannot be used for human consumption or for agriculture, although it may be appropriate for uses such as cooling power plants.

Such speculative ventures as nuclear desalination and towing icebergs from Antarctica to Los Angeles harbor are unlikely to affect the desert significantly. The Bolsa Island nuclear desalination plant proved too risky a venture even when nuclear power economies were much more favorable than at present. Currently no one except oil rich (and water poor) Middle East nations are seriously looking at the iceberg technology. The economics of the technology are not expected to provide water at a cost that can be used for agriculture in California.

Increasing the Water "Supply"

The technologies of interest are those that will increase the usable supply of water available to the California Desert. These technologies include measures that:

- Improve the quality of available water to a usable level
- Conserve existing supplies or get more use from them
- Increase the water supply.

These measures are, of course, interactive.

In water-short areas there will be extensive use of technologies that recycle waste water or desalinate agricultural run-off or high total-dissolved-solids (TDS) groundwaters for human consumption. These techniques will still be too expensive by the year 2000 for general agricultural purposes but will be cheap enough to support specialty produce grown under hydroponic or controlled environment conditions.

The potential for large-scale desalination using geothermal energy has often been mentioned. This technique might be applied to hot geothermal brine or to less saline agricultural runoffs. In the Imperial Valley a volume of fluid equal to that removed must be reinjected to prevent surface subsidence and the problems it would cause, especially to irrigated agriculture, as well as to provide a heat transfer medium for continuous heat removal from the hot rocks. Geothermal brine and other make-up water (e.g., agricultural run-off) will be reinjected. Some geothermal brines, however, are considered to be hazardous toxic wastes that should not be reinjected to groundwater formations. In other potential geothermal areas, subsidence is not so much of a problem because the surface of the earth is not used; fresh water could be produced if the economic trade-off with producing energy were favorable. This would only be expected for certain municipal and industrial water uses. The economics of desalination would be improved if the brines proved to be an economical source of certain minerals; however, this is likely only in limited circumstances.

Interest in the development of desalting processes that will convert saline water to fresh water has been increasing in the recent years. Ocean water has a dissolved salts content of about 25,000 mg/1, while in groundwater supplies dissolved salts are 1000 to 3000 mg/1. Desalting processes generally involve separation of fresh water from brine with changes of water phase, ion exchange and separation by chemical additives and electrochemical forces, and segregation of salts and water with selected permeable membranes. Some of the many processes for removing salts from water are discussed in the following paragraphs.

Reverse osmosis--Selective membranes are used to segregate water and salts. Commonly, pressure as high as 1500 psi is applied to push fresh water through the membranes. Flow rates through the membranes depend upon the initial salinity and pressure applied, which have varied from about 20 gpd/sq ft for sea water to 30 gpd/sq ft for brackish waters. Removal of excess suspended solids are necessary to prevent solids build-up on the surface of membranes. Build-up of solids can reduce the life time of membrane uses.

Electrodialysis--Ions can be removed by an electrochemical process which is an electric potential. In the process, about one gallon of waste water results for each gallon produced. Because of extremely high cost, electrodialysis is unsuitable for use with sea water.

Demineralization--Salts can be removed from water through use of ion exchangers. In this process, two different resins are used, one for the removal of cations and another for the removal of anions. The process is also prohibitively expensive for use on sea water.

Freezing--In the freezing process the temperature of the sea water is gradually lowered until ice crystals are formed. They are free of salt and can be separated from the brine.

Distillation--Water is separated from the brine by evaporation. Solar and geothermal energy can be used as heat inputs to evaporators. Scale formation inside the evaporators reduces efficiency of fresh water production rates.

To increase water supply by converting sea water to fresh water in the desert appears to be infeasible economically, because sea water generally has to be pumped considerable distances to the place of use. However, solar and geothermal energy available in the desert may make desalting processes economically attractive if the waste disposal problems can be solved.

Other technologies allow existing water supplies to be used more efficiently by reducing evaporation, using lower quality water, or by arranging water uses in cascades that can employ increasingly lower quality water. A limited amount of work is also being done to develop crops that require less water. Other approaches include the adaptation of desert plant species to agricultural practices (National Academy of Sciences, 1975). Similarly, species of useful plants are being sought that tolerate salty water, whether on a TDS basis or on a specific ion basis. Although these approaches

are not expected to find widespread application in the near term, one approach that is being rapidly adopted is trickle irrigation. This approach limits the water applied to little more than the plant's transpiration requirements. However, the procedure cannot be applied to broadcast crops. The method also allows water of lower quality to be used because less salt is applied per crop and the plant's roots can thus avoid the highly saline soil region.

Certain regions of the desert are marked by short periods of excess water and long periods of little or no water. In some of these regions, the water percolates into porous subsurface formations. In the absence of soluble minerals in the formations this water would be available from wells into the formation. Obviously, however, the rate of withdrawal could not long exceed the rate of percolation; therefore, management procedures specify safe yields from such formations.

The percolation rate can be enhanced by

- Catching available runoff, in ponds or behind dams
- Constructing artificial porous percolation beds to facilitate water seepage
- Pumping the water underground through injection wells.

Storing the water underground minimizes evaporation and stops or reverses subsidence, thereby making water available through wells. Increased percolation has been successfully applied in semiarid parts of the Western Plains states that overlie the Ogallala aquifer, which has been seriously drawn down by excessive use. This method could be used in those parts of the California desert with reliable winter rains or in years when winter rains are adequate.

In other regions of the desert, water has been locked into certain formations by geologic processes that occurred during tectonic activity. When water is withdrawn from the water-bearing formations, it is not replaced naturally; thus, the water in the nonrenewable resource is essentially mined. Many developments in arid or semiarid lands have been based on mining fossil water and have grown until demand exceeded the safe yield. Depending on the size of the development and its corresponding political influence, a demand may be created for a costly surface water importation program to "rescue" the immobile capital investments. Usually, the public bears part of the cost of these programs.

Thus, the limits or capability of a resource must be defined before unreasonable technological expectations are based on it. Appropriate techniques to define and enforce limits to development could take the form of zoning that is contingent on proven resource carrying capacity. For a nonrenewable resource, the planned period of use should be long enough for the investment to be amortized. If the resource is renewable, the level of development should not exceed the safe yield.

Defining a groundwater resource requires drilling test wells, often an expensive proposition. Alternative techniques for scanning an area cheaply and reliably do not now exist.

Not all water users require the same level of quality. Industrial practice cascades water through a series of processes that require lower and lower quality. The recent drought in California has shown that analogous practices can be carried out in the home. So-called "grey water" was collected for flushing toilets and irrigating lawns, shrubs, and gardens. In several locations, wastewater that receives only primary treatment cools power plants; wastewater receiving secondary treatment is used for watering parks, golf courses, and green belts. These practices require that used water streams be segregated, which can increase piping and pumping costs. For a municipality, a separate water distribution system for secondary treated waste water could be connected to fire hydrants and/other outlets. In a dwelling, a separate sewer and catch basin for gutters, wash basins, tubs, showers, and washing machines might be connected by a pump to lawn sprinkler systems and hose bibs. Such a system, which could be encouraged by modifications to building codes, would cost much less for new construction than for retrofitting older structures.

Conservation of the available water supply will require selection of industries in the desert that are not water intensive. Some industries require a high water flow but consume little; others consume almost the entire flow. The most desirable types of industries for the desert would require low flow, and would have even lower consumption per unit of value added. Regulating industries based on water demand is a much broader issue than water conservation alone. It is sufficient to note here that such industries exist and may become more common in the future. They include service industries and light manufacturing, mostly fabrication.

The supply of water can theoretically be increased by several technological means:

- Weather modification--The Sierra Nevada and the mountain ranges further south bar moist air masses from moving inland from the Pacific. Precipitation on both the downwind and upwind slopes of the mountain massifs can be increased by seeding winter clouds. The potential increase is not more than 15-20% of the runoff.
- Land Management--Mountain and desert runoffs can be captured by minimizing evaporation after precipitation and catching runoff before it drains out of an area. These practices include cutting timber in the mountains to enhance snow accumulation in shaded areas, removing moisture-wasting plants from stream banks, building dams and catchment basins and transferring the water from them to groundwater storage formations through percolation beds or injection wells, and lining distribution canals and channels with impervious material.

  Water Importation--the basic facilities are in place to increase imports into parts of the desert region if the institutional arrangements can be made.

  Water exploration--Sizable aquifers of rechargeable and fossil water exist in the desert and could, if found, be tapped. Adequate management criteria should be established for their use.

Weather modification remains a controversial subject, although several agencies have been seeding winter storms in California for more than 25 years. Some storms are seeded with ground-based silver iodide generators upwind of the mountains. The silver iodide mixes into the clouds through turbulent diffusion and provides nuclei for the formation of ice crystals from supercooled moisture at the theoretical maximum rate for the cloud temperature. As the moist Pacific Ocean air masses proceed east, they pass over increasingly higher mountains and their lowered temperatures theoretically precipitated more moisture. However, water precipitated downwind is not available for upwind precipitation. Once over the plains states, these storms regenerate by drawing in more moisture from the Gulf of Mexico. It is difficult to prove that weather modification definitely produces more precipitation. Obtaining good precipitation statistics is difficult when natural precipitation is variable and may otherwise be influenced by man's activities. Some carefully conducted experiments, including those conducted on the Coast range near Santa Barbara and in the southern Sierras, appear to prove the utility of the process. The Santa Barbara experiments are complicated, however, because storms off the ocean drop precipitation from successive convective bands; thus convection mechanisms are in effect as well as orographic ones.

Institutional Constraints

Whether or not it is feasible and desirable to increase the available water supply in the desert region, serious institutional impediments exist to doing so. To understand these it is necessary to understand the system that currently brings water to the California desert region. The winter snowpack in the Upper Colorado River Basin supplies most of the Colorado River's water. The supply is apportioned--by that complex of legislation, court decrees, compacts, and treaties known as the "Law of the River"--between the upper and lower basin states and the Republic of Mexico. The Colorado River Basin Act of 1968 guaranteed California's allocation at 4.4 million acre-feet per year when the Central Arizona Project goes into operation. Although project construction is yet to be finished, California has been using about 1 million acre feet more than this per year; once the project is finished, the added amount will be earmarked for Arizona, and may not be available. In anticipation of losing this excess, the Metropolitan Water District (MWD) and the Los Angeles Department of Water and Power plan other arrangements. MWD has contracted for additional water from the California Water Project, which brings water from the Sacramento-San Joaquin Delta through the Central Valley into Southern California. The state agreed by contract to provide water with a maximum TDS level of 200 ppm. However, during low-flow months and dry years, drawing the required amount of water from the Delta reverses the flow in some channels, confuses migrating fish, and allows sea water to penetrate so far upstream in the Western Delta that the point of diversion for the State Water Project is contaminated. Under these conditions, the state cannot meet its delivery commitments

for both quantity and quality.* As part of the California Water Project, a peripheral canal has been proposed to shunt water from the Sacramento River around the Delta and thereby avoid some of the Delta problems. Additional water will still have to be released from reservoirs during the dry periods to avoid salinity intrusion into the Western Delta. California has attempted to put part of the Delta outflow management burden on the federal government.† However, the courts, citing federal supremacy, have held that the federal government cannot be legally forced to do so.‡ The case may go to the Supreme Court. Alternatively, the state and federal government may reach an agreement under some other basis than the law, for the Carter administration has stated that it does not intend to usurp any state's prerogatives for managing water resources. In any event, without a peripheral canal, the California Water Project cannot meet all of its contract obligations. Support for such a canal is growing, and it will probably be built, but at escalated cost. In the meantime, some agencies holding delivery contracts cannot use the water.

The original plan contemplated development of some Northern California coastal streams when and if the California Water Project reached the limits of its capacity. The Reagan administration promised not to develop these streams, and the forecast is that delivery capability will not be exhausted until well beyond the year 2000. The State Water Project originally forecast a need to develop a North Coast increment by 1990. However, a more recent projection suggests delay until 2020 or beyond, partly because per capita use of municipal water is decreasing, probably as a result of more multiple dwelling units. It will probably be difficult for any agency to get firm commitments for more water for the desert from the California Water Project until several favorable events take place, including:

- Federal-state cooperation in maintaining Delta outflows
- Construction of a peripheral canal
- Development of North Coast streams.

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*The contracts call for water of not more than 200 ppm TDS. The state has not yet been required to meet the full quantity commitments. During the recent drought, Southern California received ample water from the Colorado River storage reservoirs (greater than 500 ppm TDS). Accordingly, delivery from Northern California was practically eliminated to allow the state to serve its hard-pressed customers in Northern California and in the Sacramento and San Joaquin Valleys.

†In Decision 1422, the State Water Resources Control Board put conditions on water rights granted to the Federal Bureau of Reclamation for diversions at the proposed New Melones Dam of the Federal Central Valley Project. Although not a matter for legal judgment, the conditions arose in part out of the Board's recognition of the need to maintain low salinity levels in the Western Delta to protect diversions that are made for municipal, industrial, and agricultural use in that area, as well as to protect fish and wildlife.

‡Opinion in case of U.S. vs. The State of California, State Water Resources Control Board, Civil No. S-3014, U.S. District Court for the Eastern District of California.

Even if these events take place, many decades will pass before their completion.

To meet its anticipated loss of Colorado River water, the Los Angeles Department of Water and Power has decided to build a second aqueduct from the Owens Valley to bring water from the snowpack runoff of the eastern slope of the Sierra Nevada. By supporting most of its water supply, the Owens Valley region was prevented from developing. Significant agricultural or industrial development in the northern desert region was probably also foreclosed. Instead, the main industry in the region is recreation and tourism. Accordingly, there is little possibility of allocating additional surface water supplies for the California Desert Region. Indeed, the California Desert Region may lose some of its existing surface water supplies.

Several possibilities must be considered with respect to reallocation of Colorado River water:

- A resolution of the Indian Water Rights Claims favorable to the Indians would change ownership of some of the water. Because the Indians could put little of this water to immediate use, they might choose to establish some sort of market system for its allocation. The cooperation of the federal government would be required to service this market, perhaps at a fee to the Indians. It is not in the Indians' best interest to force adjudication now. They would do better to wait until the water is needed for something more valuable than agriculture. They would then have a market and could get a good price. However, the energy companies will not make investments until they can be assured of a stable product price and a reliable water supply. It is of no concern to them from whom they buy the water, but if it is to be from the Indians, the sooner that arrangement is determined the better. The energy companies can buy water for little more than the farmer pays because the Indian has no alternative market. Liquid fuel shortage brought about by continuing balance of payments problems will focus interest in the mid-1980s on synthetic fuels from coal and will force the Indian water right issue. The Indians will win rights to have for their irrigable land or to develop their own mineral resources, but they will get a price from the energy companies only a little better than that paid for agricultural water.
- Significant energy development in the Colorado River basin could, during an energy shortage crisis, force decisions about priority of use. The principal energy resource in the Colorado River basin is oil shale and significant development is probably delayed beyond the year 2000.
- Energy projects in other states of the Colorado River basin that are expressly for the benefit of California might require a trade of water allocations. For example, a large coal-burning power plant or coal gasification plant in Utah built for the California energy market could cause Utah to demand reallocation of water from California's apportionment sufficient for the use of the facility and its associated infrastructure. Kiapairowits (or

its equivalent) will be resurrected in 1990 as the slack in California's electrical power capacity is used up. Nuclear power will have been rejected, hot-water geothermal facilities will be marked by operating problems, and the possibility that a drought will cut hydropower production will be faced. However, the state will probably buy water rights from the Indians rather than trade off California rights to Utah.

- Most of the agricultural water rights for California's allocation of Colorado River water have higher priority than those for municipal and industrial uses. If California's Colorado River water is reallocated because of a settlement or judgment from further interpretation of the "Law of the River," the losses would be borne first by municipal and industrial users, as was the water loss from the Central Arizona project. When the Indian water rights question is settled in the mid-1980s (within the Law of the River), the upper basin states will argue that the obligation to the Indians is a federal obligation and that therefore the lower basin states should help meet this obligation. The lower basin states will argue that their Indian obligation was settled in the Colorado River Basin Act of 1968 and that the court decision favoring the upper basin Indians under the Law of the River in no way implicated the federal government except as trustees of the rights of the Indian nations. The courts will rule in favor of the lower basin states' position, and the Law of the River will remain intact.

In summary, the Colorado River water allocation policy will be seriously tested before the year 2000, with the most serious test that of Indian water rights. Whatever the outcome, it is unlikely to have a serious impact on California Desert agriculture in the short run.

Its opponents claim that enforcement of the Reclamation Law's 160-acre limitation will bring about the end of California desert agriculture. However, a U.S. Department of Agriculture study (1978) indicates that farming in the Imperial Valley under the proposed rules of enforcement would continue to be economically viable, although less efficient. Both the state and federal governments seem ready to compromise on this issue. It seems likely, therefore, that Congress will amend the legislation, thereby mooting legal action to force the Department of Interior to enforce the 160 acre stipulation.*

As discussed above, technical possibilities exist for developing the desert by using groundwater. However, the existing groundwater law in California is inadequate to support a policy of limited development based on water resources. The law is similar to riparian rule, in which

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*In 1933 there was an administrative ruling by the U.S. Department of the Interior that the 160-acre limitation did not apply to the Imperial Irrigation District. In August 1977, the Ninth Circuit Court in San Francisco ruled in Yellen vs. Morton that acreage limitation provisions do apply to that district. It is expected that this decision will be appealed.

the landowners above percolating waters may make full use of them without regard to other landowners. The rule of correlative use, adopted by the State Supreme Court, modifies riparian rule by giving all overlying owners rights to withdraw percolating waters beneath their lands to meet his needs, when the supply is sufficient. In time of shortage, however, each owner is limited to the reasonable quantity of water needed to meet his beneficial needs, subject to similar and equal rights of all other overlying owners. Only if enough water exists to meet all owners' needs may underground waters be exported outside the basin of origin. The correlative right is part of the land and is not dependent on use (National Water Commission, 1973). Although legislation has emerged to deal with groundwater development, vexing problems of managing and administering underground basins, reservoirs, or aquifers remain:

- The extent to which the owner of groundwater has, or should have, a right to the maintenance of artesian pressures of underground water levels.
- The extent to which groundwater basins may be mined or depleted or even exhausted, and the extent to which this does or does not unlawfully interfere with earlier rights in the basin.
- The extent to which ground and surface supplies can be integrated for management purposes.

Until these and other institutional problems have been resolved, groundwater remains an uncertain resource for significant desert development. However, groundwater is being seriously considered for western energy development (e.g., the Madison formation in Wyoming), and groundwater reservoirs will play an important role in water reclamation schemes. During the recent California drought, spontaneous and unorganized use of groundwater occurred in the Sacramento and San Joaquin Valleys when thousands of wells were drilled. Thus, the potential of using groundwater to mitigate other droughts in an organized, coordinated, and managed manner should not be forgotton: the legal instruments exist to accomplish such management. In 1955, the California Legislature in the Water Replenishment District Act formed special districts empowered to levy ad valorem taxes, pump taxes, and direct charges, to exchange and import water, to replenish underground sources, and to initiate adjudication proceedings (National Water Commission, 1973).

Technological means to achieve an effective use of the existing water supply are also constrained by the difficulty in transferring water rights. A farmer in the Imperial Valley would have much more incentive to employ water conservation technology for his crops if he could readily sell the water that he is not using. At present, his main incentive is the reduced cost of water, which he must trade off against other increased costs, unless he has land for which the water saved may be used. Some water costs are

so low as to render the incentive meaningless.* Not much progress is expected in transferring water rights more easily because a water right includes not only consumptive use but withdrawal and return flow implications. Therefore, adjudicating or determining the exact water rights for specific parcels of land constitutes a complex and costly procedure.

Summary

The prospect for significant development in the California Desert region, based on increased water availability, is slight. Limited, specialized or marginal activity, primarily agricultural, based on the use of groundwater deposits, will develop but will not be extensive enough to develop the infrastructure and population necessary for attracting other industries. Existing communities will look for groundwater deposits to support growth. Extensions of existing municipalities onto or in the desert will try to meet their water needs by expanding existing sources and by conservation technologies. The implication for land use planning is to limit growth to that which existing supplies can serve. By cataloging potential sources of water and drawing up plans based on these supplies or by monitoring the growth of activities and the availability of water both technically and institutionally, planners can ensure that growth does not exceed the water required. The two approaches differ in trying to force events through central planning, in contrast to responding to contingencies as they arise. The former approach assumes knowledge and predictive powers that are difficult to achieve; the latter assumes an authority, power, and institutional will to control and limit events in the face of considerable pressure for expansion.

Although questions of Indian water rights, liquid fuel energy shortages, and out-of-state coal-fired power plants dedicated to California energy needs will call into question California's allocation of Colorado River water--in particular that portion that serves the desert area--none of these issues will force reallocation of Colorado River Water between the upper and lower basin states. The Law of the River will remain intact, and, as a matter of comity, the federal government will allow state administration of water rights to the end of the century.

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*Benefits of reclamation water take the form of interest-free construction loans and subsidized water prices. For example, the Department of the Interior has estimated the subsidy in the California Westlands project area to be $1540 per acre, which approximates the current market price for land in the district. The California Department of Water Resources has calculated that state water delivery to Westlands would cost an average of $21 per acre foot (unsubsidized), compared with the current Bureau of Reclamation price of $7.50 (subsidized) (Wilson, 1976).

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IV NEW ENERGY TECHNOLOGY

Although the California Desert has some of the most reliable solar insolation and some of the most promising hydrothermal resources in the United States, two recent SRI International studies (Ramachandran et al., 1977; Witwer et al., 1978) indicate that solar and geothermal energy developments are likely to have only limited impact on the desert within the study period. However, this conclusion is subject to many technical, economic, and institutional uncertainties.

Geothermal Energy in the California Desert

The United States Geological Survey (USGS) has estimated that vast stored heat is available for extraction and use from three types of geothermal resources in California--hydrothermal, hot dry rock, and conduction-dominated. However, much of the stored heat in these resources cannot be effectively and economically recovered. For hot dry rock and conduction-dominated geothermal energy, extraction and use technologies remain in the conceptual stage; hydrothermal energy use, on the other hand, is most promising for the near future. The locations have been identified and verified to some extent for hydrothermal resources, which are subclassified into vapor-dominated (steam) and liquid-dominated (hot water) systems. The practicability of steam for generating commercial electricity has been proven at The Geysers in Northern California. Although the use of hot water for electricity generation has not yet been commercially proven in California or elsewhere in the United States, extensive experimental work has been carried out in the Imperial Valley. And hot water is being used for commercial electricity generation in New Zealand, Mexico, Japan, and El Salvador. Hot water power plants are also under construction in the Philippines and in Iceland.

Of the hydrothermal resources in California estimated by USGS, the potential recoverable heat content in hot water is much greater than the heat content in steam because of the limitation of the steam field, as shown in Table 2. The Geysers is the only identified and proven vapor-dominated field in California; major hot water resources have been identified at four California locations--the Imperial Valley, Long Valley, Coso Hot Springs, and Surprise Valley. These are the prime locations for electricity generation in the near future and are now the focus of attention for development (for locations see Figure 3). Current projections of energy and electricity consumption in California indicate continued growth through the the rest of this century. Capacity for electricity generation, the most likely application for hydrothermal resources, will need to be expanded considerably to meet demand. The annual electricity growth rate in California to 1985 is estimated to range from 3.0 to 5.5%. An additional

Table 2

ESTIMATES OF HYDROTHERMAL RESOURCES IN CALIFORNIA

Location	Estimated Reservoir Temperature (°C)	Estimated Capacity to Support Electricity Generation for 30 Years (MW)		
		SRI	USGS	Industry Opinion
Vapor-dominated (steam)				
The Geysers	240	--	1,600	4,000-6,000
Liquid-dominated (hot water)				
Heber	175	1,000	970	6,500-8,500
Brawley	200	300	300	
Salton Sea--Niland	340	2,860	2,800	
East Mesa	180	500	490	
Coso Hot Springs	220	4,700	4,500	4,000
Long Valley	220	6,200	6,000	200 ?
Surprise Valley	175	2,000	2,100	3,000

Source: Ramachandran et al. (1977)

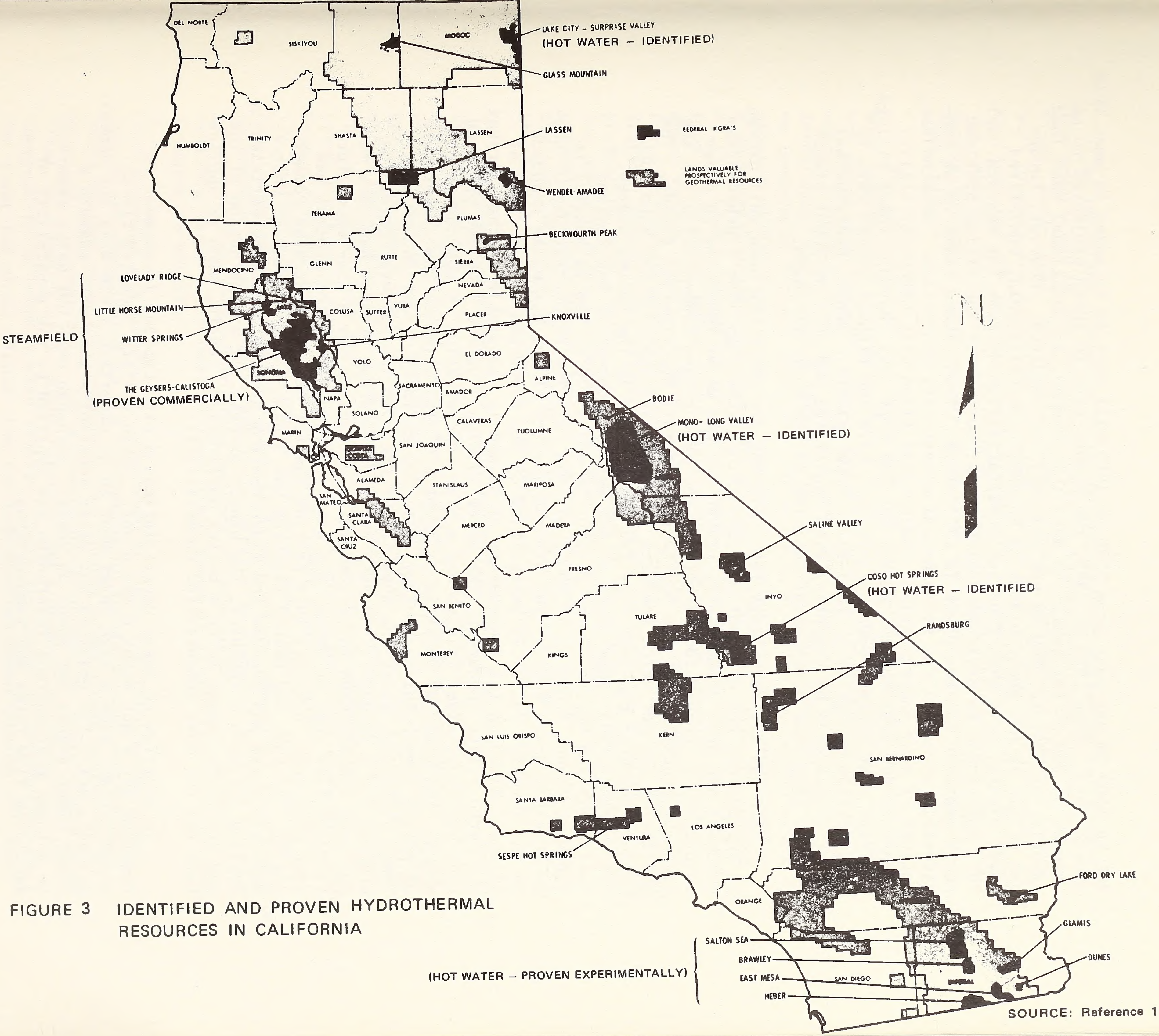

FIGURE 3 IDENTIFIED AND PROVEN HYDROTHERMAL RESOURCES IN CALIFORNIA

SOURCE: Reference 1

800 to 1500 MW per year from 1976 to 1985 will have to be added to meet this growth rate. From 1985 to 1995, the growth rate is again projected to be between 3% and 5% per year. To meet this demand, an additional base load capacity of 1900 to 3700 MW per year will be required. However, future use of oil in new power plants is uncertain in California; coal-fired power plants, even with flue gas desulfurization systems for western coal, face opposition on environmental grounds; and safety and siting problems could restrict nuclear power in California. Thus, there seems to be considerable potential for hydrothermal electricity generation. Nonetheless, because of many uncertainties, projections filed with CERCDC by utility companies for hydrothermal energy use are very low. Rather, these filings indicate that nuclear power plants will have the highest growth rate to 1995, followed closely by coal-fired power plants. Hence, hydrothermal power plants will be competing with coal-fired and nuclear power plants for new base load power plant capacity in the next few years.

Although the technology for employing dry steam has been well proven at The Geysers and at least one conversion technology (the flashed-steam process) has been commercially proven for hot water resources in other countries, no conversion technology has been proven commercially for the resource conditions in the Southern California hydrothermal fields. The quality of the hot water resource in proven applications has been much better than what has been thus far encountered in the United States. For instance, the temperature of hot water resources in New Zealand (Wairakei) and Mexico (Cerro Prieto) is above 250°C; TDS is minimal to moderate (about 3,000 to 10,000 ppm); and very low concentrations of noncondensible gases occur. The diverse quality of the hot water resource in the Imperial Valley is exemplified by the resources at Heber and at Niland. Although the temperature at Niland is comparable to the Wairakei and Cerro Prieto resources, the water is highly saline (300,000 ppm) and thus very corrosive; it also has a high concentration of noncondensible gases. The water at Heber is at about 170°-180°C (below the temperature of proven commercial technology) with low salinity (about 14,000 ppm). These conditions raise the question of the most appropriate conversion process for a resource. Because the flashed-steam process has thus far not been demonstrated to be commercially feasible for a low-temperature resource like that at Heber, the binary energy conversion process has been proposed. However, this process has not been demonstrated commercially. Because the Niland resource has a high concentration of noncondensible gases and because the flashed-steam process cannot be efficiently applied for such a resource, the binary process, or a combination of the two processes, seems to be a better application. Again, such an application has not been demonstrated commercially.

In addition to these uncertainties, a high capital investment is required for a hot water power plant. Given utility industry fiscal conservatism, such a high investment in an uncertain field will not appeal. Further, utilities required hot water reservoirs that will sustain a power plant supply for about 30 years. Although each hot water reservoir is unique, hydrothermal reservoirs are typified by the possibility of declining flow rates and temperatures.

An important criterion in using hydrothermal resources for electricity generation is the estimated price of electricity from future oil-fired, coal-fired, and nuclear power plants. Generating costs (or "bus-bar" prices) are estimated to range upward from 25 mill/kWh (constant 1976 dollars) for new plants, based on existing technologies. Table 3 compares the capital investments required for hydrothermal power plants and alternative methods of generation, as well as the prices of electricity from these plants.

The economics of hot water use for electricity generation are much more complex and uncertain than for the use of steam. Critical to using hot water are: resource price, resource quality (temperature and usable energy content), reservoir life, power plant thermal efficiency, capital investment, and capacity factor. The resource price also includes return on investment for the producer. At present, hydrothermal ventures are considered highly risky, and the required expected return on investment in a successful project is therefore put as high as 20%, after adjustment of risk from exploration and development. The bus-bar price of electricity from a hot water power plant depends heavily on the resource quality, which varies widely. Compounding this problem is that using hot water for electricity generation has not been proven commercially in the United States. Hence, cost estimates for resource exploration, development, and production vary widely, as do estimates of the capital investment required for power plants. Employing the most optimistic values for critical parameters, with mature technology for the hot water power plant assumed, the bus-bar price of electricity required can vary from 33 to 52 mills/kWh (constant 1976 dollars), depending on the resource temperature.

Because hot water power plant technology is not mature, it is desirable to have demonstration plant experience for estimating the price of electricity for commercial plants more reliably. The required bus-bar price of electricity from a demonstration plant similar to the proposed 50-MW hot water power plant at Heber in the Imperial Valley (water temperature about 180°C) can range from 46-117 mills/kWh, depending on the economic factors. The lower limit corresponds to optimistic assumptions and the upper limit to a pessimistic outlook. Demonstration plant experience should have a bearing on commercial hot water power plant economics. However, for further commercialization of hot water power plants, the required bus-bar price of electricity from first-generation commercial plants should be between 35 and 45 mills/kWh to be marginally competitive with the price of electricity from alternative methods of generation. The economic criteria required to achieve this price range will vary from one hot water resource to another.

Planning and installing transmission lines for hydrothermal power plants are complicated by the remoteness of the field and uncertainty about whether specific reservoirs can support power plant operation for 30 years. In contrast, for a conventional nuclear or fossil-fired power plant in a remote area, plant capacity and transmission lines will be designed to be economically viable. Thus, the level of uncertainty is far lower for these plants than for hydrothermal power plants. It will be difficult to plan and build a high-capacity transmission line for

Table 3

COMPARISON OF COSTS FOR FUTURE
ELECTRICITY GENERATION FACILITIES
(Constant 1976 $)

Power Plant Type	Estimated Total Capital Investment ($/kW)	Estimated Bus-Bar Price* of Electricity (mills/kWh)
Nuclear (LWR)	720-830	29
Conventional oil-fired (low-sulfur oil)	350-400	34
Combined cycle (oil-fired) (low-sulfur oil)	275-350	32
Coal-fired	570-600	29
Hydrothermal		
Steam	250-280	20
Hot water	520-800	37-47†

*For estimates, assumptions and details, see Ramachandran et al. (1977).

†Estimates for hot water reflect the difference in quality of resource.

Source: Ramachandran et al. (1977).

hydrothermal power plants in the initial stages of reservoir development because reservoir capacity has to be developed gradually in terms of small units (50 or 100 MW) of plant capacity.

Electric power can be transmitted from hot water power plants in the Imperial Valley to the nearest load centers of Los Angeles and San Diego by upgrading existing transmission lines for the first 200-MW power plant capacity through 1985. After 1985, the planned transmission line through the Imperial Valley for the Sundesert nuclear power plant could, if built, handle the anticipated growth in hot water power plants. However, a transmission line constructed solely for the hot water power, reaching to the load center (e.g., to San Diego) is estimated to increase the price of electricity by about 10-18 mills/kWh for a 200-MW capacity power plant, depending on the design of the transmission line.

A plausable scenario for the development of the Southern California hydrothermal resources might be as follows:

- In mid-1978, the U.S. Department of Energy decides to support the development of a 50-MW commercial scale demonstration plant at Heber.
- In 1982, after a 2-year operation cycle, the Heber demonstration plant achieves the estimated maximum rated capacity.
- With this operational experience many technical, economic, and institutional uncertainties are resolved, and industry and government are better prepared to decide the future development of these resources.
- Favorable resolution of the uncertainties could lead to expansion of the resource development to a dozen or more 50-100 MW size commercial power plant units by the end of the century.
- Unfavorable resolution could lead to abandonment of the resource by 1985.

Each 50-MW power plant and the wells that supply hot water will be spread over approximately 1 square mile. Although the use of directional drilling would reduce the total land area disturbed, an area of 100 acres or more may still be required for each plant. Other land use implications depend on the technology adopted. For example, in areas currently having irrigated agriculture (and possibly other multiple uses), reinjection will almost certainly be required to prevent subsidence. This will eliminate the possibility of using the condensed water for agricultural purposes as has has been suggested by some. In fact, enormous amounts of water may be required for cooling and/or reinjection. The implications of cooling water requirements (with estimates based on existing technologies for cooling methods) can be illustrated by the following example: A 50-MW power plant based on binary energy conversion process for a low-temperature resource, such as at Heber, is estimated to require initially about 190,000 gal/min cooling water; in addition, to make-up for losses, about 2700

gal/min is required. The flashed steam process for the same resource and capacity power plant would require initially about 110,000 gal/min and an additional make-up of about 3500 gal/min. Disposal of precipitated salts and the use of cooling towers will present additional environmental impacts. An H_2S problem similar to that at The Geysers is not expected to be significant for the hot water systems in the Imperial Valley.

Solar Energy in the California Desert

Nearly all of the California Desert is characterized by a daily average insolation of more than 1600 Btus--among the best-insolated areas in the United States. This high insolation has led to visions of a few hundred square miles of solar collectors in the desert filling the entire electric power needs of the United States. Unfortunately, even with a major technical breakthrough, the low efficiency and high cost of solar electric systems will prevent economically viable commercial application of solar energy to central power stations in this century. However, several less ambitious applications that have little effect on land use planning will be seen in the California Desert in this period including:

- Solar heating and cooling of buildings
- Agricultural and industrial process heat
- Thermal power
- Photovoltaics
- Wind
- Biomass.

The first five of these have varying degrees of potential for desert application. Both direct combustion of biomass and conversion of the biomass into fuels of a different form have considerable potential where water, arable land, and good insolation are available. Because biomass energy production in the desert would be severely limited by the unavailability of water for energy crop production, it is not considered to be competitive with higher valued crops on irrigated cropland. (The water problem is discussed in Sections III and V.)

The technology for solar water heating and the heating of buildings is well-established and economically competitive with other heating systems in areas with high alternative heating costs (e.g., electric resistance heating) but not in areas with cheap natural gas. Solar heating will become increasingly competitive as its technology improves and as costs of alternative fuels increase. Major technological improvement will be required to make solar cooling competitive. Current efforts to develop Rankine cycle cooling systems could lead to commercial application by 1985.

Even when solar heating and cooling have become economically competitive with other systems on a life cycle cost basis, a significant barrier remains in that solar systems have higher initial costs than competing

systems. Future operating costs which would be lower are generally heavily discounted to the detriment of solar systems. Various financial incentives may help alleviate this problem, thereby speeding acceptance of solar systems.

Solar technology is becoming economically competitive today for some agricultural and industrial heating applications where competing energy costs are high. In the agricultural sector, the most attractive uses for solar heat are in grain drying and building heating; these potential uses account for 10% of the energy use. The most attractive uses in industrial processes are those that require hot water and low temperature (180°C) steam; these potential uses represent about one-third of the energy use by industry. Most current demonstrations focus on providing hot water for commercial laundries and textile mills, and at least one brewery is using solar collectors to supply process heat. The use of solar heating systems to provide industrial steam is inhibited by the requirement to use higher priced and less developed concentrating or evacuated tube collectors. Commercial applications of solar generated industrial steam are expected to start by 1985.

Even when industrial use of solar energy would be competitive on a life cycle cost basis, two financial factors tend to inhibit its use. First, fuel costs are allowable business expenses in the year of occurrence, in contrast to the tax write-off for capital invested in solar energy over a period of years. Second, in an uncertain business environment, industry requires a short pay-back period for capital investment in contrast with the long pay-back period for solar energy.

Solar thermal power systems use some form of concentrating collectors to heat a working fluid that drives a heat engine. Three of the most promising applications are currently receiving the greatest attention: the central power station; the total energy system; and the solar irrigation system. The high capital cost projections for thermal power systems shown in Table 4 are likely to limit the potential of these systems.

The central power station is still in the design stage. The pilot plant to be built at Barstow will use conventional steam turbine technology, and is expected to provide little benefit other than experience in integrating and operating a large (and very expensive) solar power plant with a utility grid. The central receiver is not expected to reach commercial application before the end of this century. If it proves economically practicable, the central station, utility-scale system could have a large market with major impact on the desert during the next century.

Total energy systems are envisioned as installations of moderate size that would provide both the electrical and heating and cooling needs of a building complex. Total energy systems are attractive because they can permit more efficient use of solar energy which is expensive to collect. However, such systems require individual engineering designs for each installation because almost every installation will be unique. Fossil-fueled total energy systems have found few applications, at least in part,

Table 4

ECONOMICS FOR SOLAR THERMAL POWER SYSTEMS
(1975 Dollars, Southwest United States)

Generic Technology	1985	2000	2020	Comments
Central receiver				
Capital cost ($/kW)	--	$ 2,900	$ 2,100	Capacity factor* = 0.5
O&M (mills/kWh)	--	3.3	2.4	
Total energy				Nominal size = 12 MW
Capital cost ($/kW)	$ 6,800	$ 6,000	$ 5,500	Capacity factor = 0.55;
O&M (mills/kWh)				by-product hot water
By-product, hot water				Rate = 340 x 10^9 Btu/yr
Credit at $0/$10^6$ Btu	13.0	11.5	10.4	
Credit at $0.50/$10^6$ Btu	10.1	8.6	7.5	
Credit at $1.00/$10^6$ Btu	7.2	5.7	4.6	
Irrigation				
Capital cost, $/kW	$20,000	$11,000	$11,000	Capacity factor = 0.42
O&M (mills/kWh)	109	60	60	

*Amount of energy produced over a year divided by the rated capacity of the unit.

Source: Witwer et al. (1978)

because of the difficulty of integrating two independent energy demands for electricity and heat. The design of solar total energy systems will be even more complex because three independent energy flows (electricity, heat demands, and insolation) must be coordinated. Solar total energy systems are currently in the pilot stage and are not expected to be commercially viable before the end of the century.

The pumping of irrigation water could be an important application of thermal power systems, particularly in the desert. Water pumping has several technical features that make it appealing. Unlike the production of utility electricity, water pumping does not require instantaneous availability on demand; as a result storage is not critical. Furthermore, simple storage in ponds can be provided. Because many irrigation sites are located far from an electrical or gas supply, conventional energy may be expensive to supply. Finally, land requiring irrigation is generally flat, open, and inexpensive; as a result, siting the collector field should be no problem. Solar irrigation systems are currently in the pilot stage and are not expected to be commercially viable before the end of the century.

Photovoltaic devices convert sunlight directly into electricity. A solar electric energy system using photovoltaics will consist of an array of solar cells, a support structure, perhaps an optical system to concentrate the sunlight, usually a storage system, and usually power conditioning to convert dc from the cells to ac in order to interface with the system that uses the electricity. Table 5 shows the unit costs for these components. Four rows of array costs in four periods are presented; silicon (Si) and thin film cells are seen to be in the competitive range after 1985. Gallium arsenide (GaAs) cells are included because of their high conversion efficiency. Breakthrough arrays refer to the possible low costs attendant on significant technological advances. Several types of systems have been considered, ranging from simple tilted flat panel construction to tracking systems with optics that concentrate the sunlight by a factor of 1000. The designs and therefore the costs of such systems are still being developed. The numbers presented in Table 5 are typical of those found in the recent OTA report on solar energy. Analysis of the unit cost projections indicate that low concentration systems using inexpensive materials are more cost-effective than the high concentration systems with expensive, through efficient, cells.

Cost is the main hindrance to the use of photovoltaic cells as terrestrial power sources. A complete solar panel is currently available for about \$420 and will produce 19 V dc at 1.3 A with peak noontime sunshine (1 kWh/m^2). The cost equates to approximately \$17,000 per kW of peak capacity for a 12%-efficient silicon array. If the panel were to be used continuously for 20 years with no further costs incurred, the electricity produced would cost nearly \$0.50/kWh, compared with the current utility rate of about \$0.035/kWh for domestic electricity. However, even at this high rate, many currently economically viable terrestrial applications are available for photovoltaic arrays. These include uses in remote locations such as battery chargers for mountaintop weather

Table 5

PROJECTED NOMINAL UNIT COSTS FOR PHOTOVOLTAIC SYSTEMS

	1975	1985	2000	2020
Cell array ($/kW-pk)*				
Si (12%)	25,000	1,500	500	200
GaAs (20%)	200,000+	45,000	15,000	10,000
Thin films (7%)	---	1,500	500	200
Breakthrough (40%)	---	1,200	250	75
Support structure ($/m^2)				
Nonconcentrating	15	15	15	15
5x concentrating nontracking	--	60	40	25
1,000x concentrating	150	120	100	80
Power conditioning ($/kW)	200	150	70	50
Storage ($/kWh)	80	55	30	30

*Cell conversion efficiencies are shown in parentheses.

Source: Witwer et al. (1978)

stations, radio repeater stations, forest lookout towers, warning lights for offshore structures and channel buoys, and cathodic corrosion inhibitors for pipelines. A recent study by the BDM Corporation for DoD indicates that photovoltaic devices are currently economically competitive for a large number of remote military uses. The market size was estimated to be at least 100 MW per year. The military and other government sectors are now experimenting with the use of photovoltaic solar energy converters for normal daily use.

The applications that can be expected from photovoltaic energy systems depend greatly on technological advancements to reduce the production costs of photovoltaic devices. A major breakthrough allowing a large cost reduction would permit these systems not only to compete well in distributed applications but to capture a share of the electric power market as peak and intermediate load central station power systems. Less dramatic cost reductions could limit the installation of photovoltaic devices to distributed applications. Central power station applications should not be expected before the end of the century.

In comparison with the other solar technologies that provide electricity, photovoltaic systems are inherently well-suited to distributed applications. This is due to the potential economic viability of these systems, even in small sizes, and their low maintenance requirements. Photovoltaic systems also have an advantage over several other solar energy technologies in that they can use indirect sunlight. Solar thermal power stations, on the other hand, require direct insolation for operation. This is an important consideration that may allow photovoltaic energy contributions in areas where other solar technologies cannot compete because of the problem of frequent cloud cover.

For centuries wind machines, such as the slow speed Dutch windmills, have been converting indirect solar energy (in the form of wind) into useful work. Within the last 50 years, the development of electrical machinery has led to generating electricity with high-speed wind turbines, commonly called a wind turbine generator (WTG). When a WTG is used with storage or is tied into an electrical grid, it is called a Wind Energy Conversion System (WECS).

Horizontal axis turbines may well be economically practicable today. Large-diameter WTGs in areas of moderately high mean wind speed may produce electricity at a cost that is competitive with electricity from fuel oil. With increasing oil costs, shorter payback periods may be possible, and wind turbine applications in areas with lower wind velocities may become practicable.

The three WTG generic technologies that appear to be the most likely candidates for economic generation of electricity are:

- A 1.5-MW two-bladed horizontal axis WTG (similar to the Model II design of DOE)
- A 500-kW Darrieus vertical axis WTG
- A 15-kW three-bladed horizontal axis WTG.

Horizontal machines represent proved technology and can be constructed to take advantage of economies of scale. (The power available varies as the diameter squared.) The economics of wind machines depends heavily on mean wind velocities because the power produced varies as the wind velocity cubed. For example, a large, 1.5-MW WTG may be economical at a mean wind speed of 15 miles per hour (at about 200 feet above the ground, the approximate height of the wind system axis). In locations with higher mean wind speeds, smaller WTGs can be deployed to achieve similar economies.

The 15-kW WTG unit is now commercially available and might be purchased by a farmer or homeowner. It is rated at 15 kW at 26 mph and 3.5 kW at 15 mph. The current economic viability of these small units has yet to be firmly established, but the opportunities for a significant reduction in price may be high because of the large potential market. Many sites in the California Desert (especially on exposed ridges and mountain tops) have potentially useful levels of wind energy.

Numerous recent studies have suggested that megawatt-scale WTG units could be economically attractive today if utilities had sufficient experience with wind to understand system integration issues and if at the same time capable supply channels were developed. At current funding levels, WGT units are expected to enter commercial use by 1985, with the Darrius following in about 5 years. At least 10 designs for 15-kW WTGs are commercially available today. Significant market penetration of these machines will be a function of future alternative fuel costs for electric power generation, as well as the investment incentives that may become available. Technical barriers to the implementation of the schedule are minor.

The estimated costs for the generic wind systems are shown in Table 6. The system costs in this table are based on a location with a 15-mph average wind velocity. At such a site, a capacity factor of 0.5 could be expected.

Table 6

ECONOMICS FOR WIND ENERGY SYSTEMS
(1975 Dollars)

Generic Technology	1985	2000	2020
1.5-MW, horizontal axis WTG			
Capital cost, \$/kW	870	830	820
O&M, mills/kWh	6.0	5.7	5.6
500-kW, Darrieus vertical axis WTG			
Capital cost, \$/kW	1200	1100	1050
O&M, mills/kWh	8.2	7.5	7.2
15-kW, 3-blade, horizontal axis WTG			
Capital cost, \$/kW	1200	1200	1200
O&M, mills/kWh	8.2	8.2	8.2

Source: Witwer et al. (1978)

The mechanical power that WTGs produce can be used directly for mechanical tasks (e.g., to pump water) or can be simply and efficiently converted into electricity or heat. Two of the most attractive applications appear to be utility electricity and agricultural water pumping.

The introduction of wind-generated electricity onto an electrical grid can give rise to several concerns. Because accurate prediction of the availability of wind is not possible and because electrical storage costs are high for the majority of utilities, it will be necessary to provide conventional generating facilities as backup. The economic value of the WTG thus becomes simply the savings in fuel, operating, and maintenance expenses caused by reduction in operation of conventional units. This is commonly referred to as a "fuel saver mode" of operation.

Small wind units for off-grid applications, such as water pumping were in common use in the United States several decades ago, but fell out of favor, largely because of the availability of federally supported, low-cost electricity. Many of these units are now being refurbished because of the increasing costs of electric power. Water pumping applications can be attractive for several reasons: Because storing pumped water in ponds or tanks is simple, wind fluctuations can be accommodated; and because providing electrical power or combustible fuel to a remote well can be very expensive, the economics of WTG can be favorable.

Off-grid electrical applications of small WTGs can also be attractive when wind speeds are high and transmission distances are great. However, the cost of this power will be considerably greater than that for grid-supplied power because of the high cost of electrical storage and because of the higher cost (per unit of capacity) of smaller WTGs.

WECSs produce electrical power without the production of atmospheric emissions. Because these systems will be located in windy areas, which may coincide with scenic hills and mountains, their aesthetic impacts may cause difficulty in site selection. The disruption of TV reception in the proximity of a WTG is a problem that can be alleviated through the use of cable TV in populated areas or nonmetallic WTG blades. The TV problem could cause special difficulties in the siting of the small, 5- to 50-kW WTGs that are likely to be sited near populated areas.

Implications for Land Use Planning

The implications of developing energy technologies for land use planning for the California Desert are fraught with uncertainty. If the geothermal demonstration facility at Heber is built, it will significantly disrupt roughly 1 square mile of land and bring a modest population increase to the area during and after the construction. If the program is continued, a similar effect can be expected for each additional unit. However, the construction of more than one unit in this century is not probable in view of unresolved problems.

A gradual transition to solar heating and cooling systems and to agricultural and industrial process heat systems should occur as (1) the technology improves, (2) the cost of other fuel sources increases, and (3) these systems gain public acceptance. The use of photovoltaic systems, wind systems, and solar thermal irrigation systems can be expected to increase in special situations to which they are well adapted. Large shifts to solar energy should not be expected in this century without significant government intervention unless alternative fuels become unexpectedly expensive or are unexpectedly cut off. Nor will solar energy systems permit widespread off-grid use because backup systems are required for most applications.

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V DESERT AGRICULTURE TECHNOLOGY

Two main technological thrusts in agricultural research may significantly affect the CDCA. The first includes methods for improving the productivity of existing desert agriculture, with concurrent reduction of water and energy consumption. Among the major research activities under way in this area are: more efficient ways to apply water and nutrients to plants: genetically improved strains of crops and animals; new farm machinery that reduces the need for unskilled labor but increases the need for relatively skilled labor; pest management techniques to gradually supplement the present reliance on chemicals to control insects, other pests and diseases; research into psychological and physiological stress factors affecting animals; and the expansion of local industry to include processing and packing plants. Many of these activities require technology transfer from other areas rather than the development of new technology.

The second major development is the search, prompted by the energy crisis and political events in the United States and abroad, for new crops that can be grown profitably in the desert's highly saline soils and arid environment. Jojoba, a plant that produces a substitute for sperm oil, and guayule, a plant that at one time was a major source of natural rubber for the United States, are the "new crops" that have been receiving the most attention for production within the study period. Because both are grown extensively in Mexico, their development in the CDCA would require little new technology. For the longer term, there is interest in other kinds of crops, including many indigenous plants grown in the Sonoran Desert that have long been used for food and pharmaceuticals by local populations. Proponents suggest that some of these may become important food crops in the future. More often cited are proposals to stimulate desert biomass production for energy conversion; mesquite and the genus Euphorbia are listed as possibilities, the former for its high heating value (i.e., high Btu lb) and the latter because there are indications that it can be converted into synthetic petroleum. The economics of most of these proposals are currently uncertain.

Large-scale innovations in agriculture, except in times of national emergency, generally occur over long periods. Barring a breakthrough in biomass energy production techniques and a concerted government policy to exploit the same, most new technologies affecting desert agriculture will be introduced gradually (e.g., drip irrigation systems now being integrated into some desert farms). In particular, innovations that improve productivity are most likely to be implemented in areas where agriculture is already well established and for crops or livestock already being raised in the CDCA. Major innovations in crops, energy,

or raw materials are unlikely to become a major factor in desert agriculture before the 1990s, although institutional forces accelerate the process.

The agricultural sector has a highly effective system for R&D and technology transfer. For the most part, agricultural R&D is user-oriented; research in universities is frequently coordinated with field extension offices, where state or federal agents work closely with farmers and ranchers. The technology transfer system is comprised of the U.S. Department of Agriculture; the University of California with major research at the Davis, Berkeley, and Riverside campuses and extension services in all agricultural counties; state agricultural offices and their extension services; and private companies manufacturing and selling technology to agribusiness.

International efforts are potentially important to the CDCA's agricultural base. Most important development takes place under the auspices of United Nations agencies. In addition, Israel has developed technologies to exploit their arid lands for food production.

Technologies Improving Overall Productivity

Although a wide range of research intended to improve unit production for specific crops is under way, most of it is too detailed to report here. Major areas of development that will likely lead to improved techniques or better farm machinery include: genetics, water and nutrient application systems, energy development, animal stress research, and farm management.

Genetics

For desert crops, genetic research has improved crops' pest resistance and their ability to grow in highly saline, dry soils; plants have also been developed to take advantage of the longer growing season in the desert area. Because desert agriculture is more expensive than that in the other major growing areas of the state, many crops are grown profitably in the CDCA only because they can be harvested and marketed earlier in the growing season than can the same crops grown in other areas. Respondents familiar with CDCA agriculture indicated the following developments were likely to affect desert agriculture within the next 20 years:

- Improvements in the pest resistance of alfalfa, cotton, barley, and sugar beets.
- The long-term replacement of chemicals for fighting plant disease by developing disease-resistant plant strains.
- Increased salt tolerance of local crops.
- Increased tolerance to the desert climate, especially summer heat.

Developing pest- and disease-resistant crop strains is a long-term process. Most authorities expect more flexible and more versatile pesticides and systemics will continue to be developed for disease and

pest control; however, they also indicate a trend toward more integrated pest management--less use of environmentally dangerous chemicals, and more use of resistant plant varieties, pheromones and juvenile hormone analogs, and environmental monitoring networks (Witwer, 1975).

Research on increasing photosynthesis will also be important by making three-carbon plants grow like more efficient four-carbon crops (Zelitch, 1975), as well as the development of more crop varieties that, like the legumes, are able to fix nitrogen biologically (Agricultural Research and Research Education Hearings, 1977). Both techniques could greatly improve the energy efficiency of agriculture, the former by increasing the efficiency of plants in using the sun's energy, and the latter by reducing demand for energy-intensive chemical fertilizers (and thereby reducing agricultural chemical waste products). Both techniques are considered long-term strategies.

Irrigation Systems

Because desert agriculture is inherently short of water, considerable attention has been paid to developing more efficient water transport and application systems. Major innovations in two kinds of irrigation technology are already having important effects in the CDCA's growing areas: drip irrigation and sprinklers.

Drip irrigation, which is ideal for some orchards and vineyards as well as some row crops in the desert, has expanded rapidly since the late 1960s. The technique, which was first developed in Palestine in the 1930s,

> ...consists in laying a plastic tube of small diameter on the surface of a field alongside the plants and delivering water to the plants slowly but frequently from holes or special emitters located at approximate points along the tube (Shoji, 1977).

Although drip irrigation is not effective for all crops (e.g., too much tubing is required for crops that grow close together) it works especially well for high-value crops grown in the salty, dry, sandy soils of the desert. Drip irrigation can also be used to apply specified quantities of nutrients and disease control chemicals to each plant. On the whole, drip irrigation uses less water and less labor but requires somewhat more energy than gravity systems. Drip irrigation in the CDCA is expected to increase through the 1980s.

Refinements in sprinkler systems, (e.g., development of nozzles emitting smaller amounts of water) for irrigation and feeding nutrients and chemicals to plants are also important to desert agriculture because many of the crops grown in the CDCA cannot be irrigated by drip techniques. Sprinkler systems are more effective for densely planted crops than drip systems, but sprinklers make even distribution of water and nutrients more difficult. They are also less useful in windy areas. Sprinkler

and drip systems require more highly skilled labor than do traditional flooding and furrow systems, and both are more energy-intensive.

Other technologies potentially significant for irrigation include:

- Advances in furrow systems operation (e.g., lasers to control flooding by monitoring water levels and electronic gate control systems).
- Development of closed environments for desert agriculture, (e.g., the extensive use of greenhouses) (Bazell, 1971).
- Development of water and nutrient recycling systems.

Farm and Ranch Management's Equipment

Although no startling advances in technology are expected, developments in other areas and growing demands for information from federal and state agencies are likely to mean major changes in how farms are managed. New management techniques will be needed for the changing roles and practices of farm labor, especially with the increasing unionization of farm workers in California. Legislative requirements for reports of different kinds will require farmers to formalize their record keeping systems. Rising labor costs will mean increasing mechanization, and because machinery will also be more expensive to purchase and operate and more complex, effective ways to manage its use will be needed. Finally, the two critical factors in desert agriculture, energy and water, will probably continue to be in short supply, and management technology--some of which has been discussed previously--will be required to optimize their use.

Although trends are now discernible, computers are likely to play an increasing role in agriculture in making more efficient administrative activities and in controlling irrigation, application of nutrients, pesticides, herbicides, and the like. Requirements of California farm labor law, for example, have led some farmers to use computers to store employment records. Larger farms owned by companies like Tenneco, Sun World, and Superior Oil, use computers extensively to control irrigation and other equipment. Computer service agencies in the CDCA already provide smaller farmers with financial, record keeping, and other management services. Given the expected computer price decline--especially in microcomputers--and increased ease in using them, considerable growth in computers employed on small farms, especially during the 1980s, will almost certainly occur. Likewise, substantial growth can be expected in sophisticated microprocessors and control systems for farm equipment.

A recently published forecast of turn-of-the-century farm equipment is illustrative of the degree of change possible during the next 20 years:

> By the year 2001 field machines will be controlled by computer tapes and guided buried wires or sensing devices.

> Soil compaction thus will cease to be a problem because tractors and other field equipment do not contact the soil areas in which crops are grown. Instead, equipment traffic lanes will be used to improve traction and to channel the rainfall to the crops. A network of subsurface irrigation and sensing wires will be below those traffic lanes.
>
> One operator then can monitor the automated movement of a fleet of field machines from a control tower. These self-propelled machines can harvest and process one crop as they will simultaneously prepare the seed-bed and plant another crop in the same pass. Some airborne equipment can apply fertilizer and chemicals on the larger farms. Land will be double-cropped, even triple-cropped to achieve the needed production.
>
> ...field equipment will be powered by nuclear energy or electro-mechanical energy. Solar heating systems are built into the superstructures of buildings to provide energy for crop drying and for human and animal comfort heating.
>
> Farmers no longer buy individual pieces of equipment but entire systems that provide the appropriate degree of mechanization for their operations. Complete computerized equipment summaries will provide reliable management aids.
>
> Vegetable crops will be grown in huge greenhouses located near the markets. Solar energy maintains the greenhouse environment plus energy for other routine needs. Because the production will be near the consumer, fresh vegetables and small fruit can be delivered daily. And that energy saved in transportation and extra refrigeration is greater than the auxiliary energy that might be required for production even in a hostile climate.
>
> --Food Engineering, September 1977

Some of these forecasts are somewhat optimistic, but the potential for automation they cite is probably accurate.

Although technological improvements are not an important factor, several respondents indicated that the movement of food processing and packing plants into CDCA agricultural areas, especially the Imperial Valley, would be possible and profitable if adequate and relatively inexpensive energy becomes available. To a certain extent, this will be related to the development of geothermal, nuclear, solar, or other energy production facilities in or near the area.

Livestock

The CDCA's hot summer climate and shortage of locally available feedstocks and feed currently make most livestock agriculture only marginally profitable, if at all. Technological "solutions" now under way to these problems include the following:

- Utilizing organic by-products and crop residues. Slightly spoiled food from commercial markets, for example, is more than adequate as feed for animals. Similarly, crops, including wheat straw, have residues that remain after harvesting and that can be treated for feed.
- Utilizing cattle manure to generate methane gas. This process is already being developed commercially in other parts of the United States and could prove profitable in the CDCA as the price of natural gas and liquified natural gas (LNG) continues to rise and as solar or geothermal energy becomes available in the CDCA to make treatment easier. Also noted are attempts to treat animal waste products to produce cattle feed.
- Significantly reducing the cost of area livestock by moving processing and packing plants to the CDCA. Such movement depends largely on the availability and price of local energy sources, and on external price factors.
- Combining aquaculture with agriculture. Fish could be raised in specially designed ponds integrated into present irrigation systems; the fish could be fed on treated animal waste products and raised for petfood.
- Using new crops for cattle feed (e.g., mesquite and screw beans, which in some cases are not crops, but simply plants indigenous to the desert area).
- Employing shower systems and changes in diets to reduce losses in cattle productivity from heat.
- Raising lambs to take advantage of milder desert winters.
- Developing genetic techniques to produce more adaptable and productive cattle and sheep.

Energy and Agriculture

Agriculture interests stressed the potential usefulness of geothermal resources for agriculture (See Section IV). They expect electrical energy and purified water from these developments to help agriculture in the area by

- Reducing the expense of operating electrical sprinklers and greenhouses.
- Making energy available for freezer and processing plants.

Several respondents noted that wind energy systems between Riverside and Indio would help reduce overall energy costs.

In general, the availability and cost of energy are important to desert agriculture. Most respondents assume that more energy at lower prices will improve the profitability of agriculture in the area. However, energy resources that cause air or water pollution or require large amounts of the scarce water would generally have negative effects on desert agriculture.

The Potential for New Crops in the Desert Area

Although research into new desert crops is varied, most short-term interest focuses on two crops that have been grown commercially elsewhere.

Jojoba (*Simmondsia chinensis*) produces a seed that is 60% light, liquid wax almost identical to industrially important oil of the sperm whale. The United States has forbidden importation of sperm whale oil since 1970 and international sanctions have been imposed on killing sperm whales. Thus, with decreasing stockpiles, this important oil will become increasingly scarce. Conversely, the market for the jojoba substitute is expected to grow sharply (Maugh, 1977).

Jojoba is particularly suited to the desert area. It needs little or no irrigation, and it tolerates saline and alkaline soils and saline irrigation water. The federal government is encouraging it as a crop to improve the economic self-sufficiency of several Indian reservations in California and Arizona. Commercial organizations, among them the Tenneco Corporation, are also reported to be interested.

Guayule (*Parthenium argentatum*) was used as a source of rubber in the early part of this century and during World War II. Given international economic and political factors, the United States is considering turning to domestic sources for natural rubber. Currently, U.S. research is under way, and a pilot commercial plant in Mexico is using guayule. Collaboration between the two countries is considered likely, but widespread commercial growing of guayule in this country (and the CDCA) is unlikely before the late 1980s (Maugh, 1977).

Researchers have suggested other new crops to help alleviate the energy crisis, to reduce reliance on imports of certain raw materials, to provide food, and to produce feedstocks for animals. Most of these are unlikely to become large-scale commercial ventures in the CDCA until after the 20-year period on which this study focuses. However, they are of potential importance, especially if economic or political events speed their development as commercial crops.

- Mesquite (*Prosopis juliflora* and related species) has been proposed as a low-energy and low-water crop for livestock and human consumption. Indians along the lower Colorado used mesquite pods for food, and mesquite has been raised in Hawaii and elsewhere as a source of cattlefeed (Felker and Waines, ND).
- Lesquerella, like jojoba, produces oil seeds (Maugh, 1977).

- Sesame (Sesamum indicum) produces oil seeds and may already be under commercial production in the Southwestern United States (Maugh, 1977).
- Euphorbia lathyrus (known as the gopher plant in California) and Euphorbia tirucalli have been proposed by Melvin Calvin at the University of California at Berkeley as candidates for producing useful energy products (Science, October 1, 1976).
- The buffalo gourd (Cucurbita foetidissima) produces an edible oil, containing as much as 35% protein (Felger and Nabhan, 1978; Maugh, 1977).
- Euphorbia antisyphilitica, or candelilla, produces a commercial wax, 5,000,000 kg of which are imported from Mexico each year (Maugh, 1977).
- Chaparral (a combination of plant species depending on the location and the age of the chaparral stand) has a relatively high heating value and has been suggested as a potential biomass energy resource (Teknetron, Inc., March 1977).
- The use of waste waters and marginal cropland for growing algae to in turn produce methane has been studied for its biomass potential for the desert as well as other areas (Ward, Jeffries, and Timourian, 1977; Benemann, 1977).
- The use of salt-tolerant plants that also remove salt from the soil, is under study (Stebbins, Papenfuss, and Amamoto, 1977).

Of course, many other plants also have long-range commercial crop potential for the desert area, but the ones indicated here are those most frequently referred to in the literature and by respondents.

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VI DESERT RECREATION TECHNOLOGY

Introduction

In spite of the major role technologies play in recreation, specialists in the field have paid surprisingly little attention to the potential effects of future technologies on recreation and the environments in which recreation takes place. For the most part, other factors (e.g., the proximity of populations, site-specific characteristics, economic factors, and current leisure and recreation patterns) provide the basis for recreation demand forecasts (Cicchetti, 1973); recreation planners rarely consider technological advances related to demand important (Shafer, Moeller, Morrison, and Getty, 1974).

Technology, however, has not been completely ignored. In particular, environmental impacts and other problems associated with technology in recreation have helped focus concerns on the role and nature of such technologies. In the CDCA, for example, the widespread popularity of off-road vehicles (ORVs) and associated problems has been and continues to be a major issue. Naturally, both recreation authorities and stakeholder groups tend to pay the most attention to the most visibly damaging activities.

Summary

Most authorities pay the most attention to technologies that underlie present problems. Highlights of our review of potential future recreation technologies include the following:*

- Vehicles for recreation--In the short term, improvements in ORV technology will make vehicles, especially 4-wheel drives (4WD), more powerful and easier to handle in varying terrains. Improved ORVs are unlikely to increase in price any faster than the overall rate of inflation. In general, expected improvements in automotive technology due to the requirements of federal energy, emissions, and safety regulations will increase the attractiveness of light trucks (pickups, 4WDs, and vans), dune buggies, motorcycles, and the like, for which regulations will go into effect later than for larger vehicles. Airborne craft that are either pulled by or at least launched from moving

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*Recreation technology has been grouped in several major categories here, reflecting viewpoints in the literature and of our respondents.

ground vehicles are likely to become better made and cheaper, thus increasing demand for them. In the longer run, several "exotic" vehicles may be marketed, among them air cushion vehicles (ACVs) or ground effect machines and jet backpacks; most of these, however, appear to be too expensive to have really mass appeal.

- Shelter--Especially important in the desert will be improved stationary and mobile shelters for individuals and groups, including: recreational vehicles, campers and vans; small, portable shelters like tents designed especially for the desert environment; larger, sometimes permanent structures that use desert resources efficiently to provide comfort and to ensure survival; and clothing and equipment designed for the desert. In keeping with rising interest in "appropriate technology," "soft energy," recyclability, and similar approaches to technology, a movement is likely in which structures and equipment consistent with these principles are designed for use in the deserts. Solar and wind energy systems, waste and water recycling devices, lightweight and reflective plastics, portable communications equipment, and microcomputer controlled environments are likely to be demonstrated on a moderate scale over the next 5 to 10 years. Camping gear, on the other hand, may derive innovations from the space program and other materials research that are gradually transferred to consumer camping gear. In part, these developments will depend on advertising campaigns and, in part, on increases in CDCA population. In the longer run, and for the very few, more exotic kinds of mobile shelters may become somewhat move available than at present (e.g., a recreational vehicle consisting of a camper inside a large helicopter).

- Recreation management--Developments in microprocessor, communications, and satellite technology will rapidly provide the foundations for monitoring, controlling access to, and managing desert recreation areas. In general, few authorities cite developments in this area as important, but one major forecast of the future of leisure environments reported numerous examples in which technology could enhance recreation management (Shafer, Moeller, Morrison and Getty, 1974). Many studies of outdoor recreation needs and forecasts of future developments indicate that "recreation information systems" and "reservation systems" will become increasingly pervasive. Some systems for state and national parks already exist, and, by the mid-1990s, information on facilities, immediate availability, long-term reservations, and so on will be customarily handled through widely accessible, computer-based information systems.

- Other technologies--Although difficult to identify, improvements in technology that enhance more benign kinds of desert recreation can be expected. Desert health spas, new national or state parks and monument sites, and educational facilities

focusing attention on the natural desert environment or on archaeological diggings may increase general tourism as well as sightseeing, walking, photography, and related activities. Breakthroughs in desalination of water (or, alternatively, the unlikely occurrence of inexpensive energy production in the desert) could lead to the development of man-made lakes, and associated water sports.

Vehicles--Ground, Air, and Water

The use of motorized vehicles, especially ORVs, for recreation in the desert is likely to be enhanced by near-term changes in technology; regulation, on the other hand, is likely to attempt to curtail or eliminate ORV use in uncontrolled areas, aiming rather to channel ORV activities into well-defined areas. Technological factors include:

- The general shift in public interest away from second and third autos toward light trucks or utility vehicles has enabled the automobile industry to maintain both the image and effects of high powered, heavy duty vehicles in light trucks (vans, pickups, and especially 4WDs). Better automotive technology coming from the across-the-board improvements required by federal laws will also be employed in the less regulated truck marketplace.
- Lighter and stronger materials, more efficient transmissions, more energy-efficient engines (although still large and powerful), and, in the longer run, engines able to use fuels other than gasoline or diesel fuel will alter light recreational vehicles and ORVs.
- Larger tires for 4WDs (greater flotation and road clearance) will make off-road use more comfortable.
- Smaller, less powerful, but still adequate 4WDs like the Subaru BRAT are extending the appeal of these kinds of vehicles to new groups of people otherwise less inclined toward ORVs.
- By the early 1980s, front wheel drive (FWD) automobiles and vans will be commonplace in the new U.S. automobile fleet. Although not true ORVs, FWDs will be easier to use on poorer road surfaces, and their expected market penetration may lead to increased use of unsurfaced roads, dry washes, and so forth. Aftermarket conversion shops will accompany FWD automobiles and light trucks, many working to improve both the performance and comfort of FWDs. Typically, aftermarket conversion facilities of this sort begin in Southern California; thus, their products are likely to appear rather quickly in the desert, probably by the early 1980s.

- With increasing van popularity, it is quite likely that van-sized or configured campers will replace (or at least supplement) traditional and larger recreation vehicle (RV) campers. Lighter camper vans with more powerful engines and FWD will have much greater flexibility in where they can go than conventional large campers. Similarly, a fusion of 4WD pickups and ORVs (like the Ford Bronco or the GMC Jimmy) with camper systems would increase desert camping.

- By the 1990s, basic utility vehicles with modular components will probably find their way into the domestic automobile fleet. There is little doubt that recreational configurations will be available, and thus a family able to afford only one vehicle could have a utility vehicle that could be used for multiple purposes, including recreation.

- Off-road motorcycles will be improved in the near future: a shift from two-stroke to four-stroke engines, resulting in lower noise; gearboxes designed for wider operating ranges and extremely high performance (motocross); and, in the longer run, engines that can use alternative fuels like methanol. For the most part, these changes will tend to increase the popularity of off road motorcycles.

- An increase in the number of small, open, three- or four-wheel all-terrain vehicles (ATVs) can be expected, most of them coming from Japanese or European manufacturers entering the field.

- Unpowered or low-powered (moped) off-road bicycles are beginning to be available. Small, light, and easy to carry on the roof or back of a car, these are likely to increase in popularity as they afford camper owners with additional mobility at low cost.

Along with the growth in use of ORVs, there are indications that small, inexpensive flying craft (e.g., hang gliders, gyrocopters, parakites, and balloons) are becoming increasingly popular in desert and other areas. New technology of potential interest may include:

- Human-powered flight, based on future sophistication of craft like the recent Kremer Prize winner, the Gossamer Condor (Meredith, 1978), is likely to become a new sport in desert areas with low or negligible wind.

- Motorized parafoils, a combination of parachute, airfoil, and small motor that is now being developed for military applications, may become the basis for several generations of individualized recreational flying equipment (Newsweek, April 3, 1978).

- Improvements in hang glider technology, especially the recent addition of small engines, will improve the safety and handling characteristics of hang gliders, and extend their areas of use and popularity.

- Improvements in lighter-than-air craft (LTAs) can be expected, and sport ballooning may become a popular desert sport. One respondent suggested that a solar-powered hot air balloon would prove a popular combination of LTA flight and environmentally attractive technology.

- Small improvements in technology should lower prices and enhance the attractiveness of sports like gliding, sport parachuting, and skydiving. In general, recreational flying should grow in the desert, although more because of a shift of general aviation toward desert areas than because of new technology.

In addition, a whole spectrum of "Buck Rogers" recreation technology looms on the near horizon; no doubt, some of these will find their way into the marketplace and into use in desert areas. At present, all are too expensive to be considered consumer recreation technology; some, however, could be purchased jointly by groups in the near future. The more exotic airborne recreation technology already available includes:

- The "Discojet," a flying saucer-like aircraft currently available as a prototype at a cost of more than $1,000,000 (Sakowitz Christmas Catalogue, 1977).

- Consumer jet backpacks designed to lift one person; slightly larger versions could power small platforms that could carry several persons.

- Hovercraft (air cushion vehicles, or ACVs) are already available, but they are expensive and would probably have limited application in desert areas. They work ideally on bodies of water; over land their airstream creates clouds of dirt or sand, and they perform only marginally over uneven or steep terrains.

- An offshoot of large convenience campers, a helicopter-borne camper (the Itasca Heli-Home) is now available for $300,000, including a modified Sikorsky S-58 helicopter (McKeown, 1977).

Given present conditions, recreational boating has little application in a desert area with few natural lakes. Incremental advances in boat technology will improve both power and sail boats, in most cases making them easier to operate and slightly less expensive (in real terms) than at present. However, few "new" technologies appear to have the potential for noticeably changing recreation patterns in the CDCA; those that could, assuming the expansion of existing lakes or the development of artificial lakes, include:

- ACVs

- Motorized surfboards and other one-person watercraft

- Small hydrofoils

- Improved windsurfers.

For the most part, improvements in boats and increased use will primarily affect traffic through the CDCA, as more people drive to Lake Mead in Nevada or to the Colorado River in Arizona.

Shelter, Clothing, and Camping Equipment

Many people perceive the desert to be a relatively hostile and inhospitable environment. Some recreation professionals suggest that two thrusts, one of them educational and the other technological, will help change these attitudes within the next 20 years. In the first place, much of the desert is extremely hot only during the summer months, and then only during daytime. Some areas of the desert, in fact, have longer "recreation seasons" than do more popular mountain areas that are closed during the winter months. Federal, state, and county park and recreation agencies are likely to disseminate more information about the climatic, recreational, historical, and environmental attractiveness of the desert to the public.

At the same time, designers and manufacturers of shelters and equipment for recreation will turn their attention to the desert environment. Some will see the desert as an ideal place to design, build, and demonstrate technology that relies mostly on renewable and recyclable resources and that is environmentally sensitive. Others will focus on developing camping equipment that meets the climatic requirements of the desert. Along both of these lines of development, potentially significant developments may include:

- Development of desert power sources--typically solar or wind powered--to supply heating, cooling, and electricity to small communities and structures in the desert. The self-containment and self-sufficiency of the power source will increase their use for recreational activities.
- Efficient use of recycled water and organic wastes for desert-grown foodstuffs.
- Park transportation systems designed to (a) reduce the use of automobiles within environmentally fragile areas and (b) move large numbers of visitors about in relative comfort. Park mass transit (like that in Yosemite National Park) and electric rental automobiles are examples of such innovations.
- Desert recreation shelters are being designed around local themes. An example is the current proposal to develop a desert visitor's center north of Indio in Riverside County. To be designed by Paolo Soleri and to be operated by the County Parks Department, the center will be structured around complementary themes of environmental sensitivity by incorporating local Indian communities and culture, the palm oases indigenous to the area, the geology of the area, and desert lifestyles.
- By no means all of the design emphasis for desert shelters will revolve around the environmental and energy. Improved building technology is likely to lead to small, scattered desert health

spas, religious and secular retreats, and educational centers for groups like the Sierra Club and Outward Bound. In other words, building design will provide recreation clientele with the natural benefits of the desert (including, on the one hand, a healthy climate, and, on the other--for example--the mystical attraction the desert holds for some).

- Microprocessor control systems will probably play a large role in controlling shelter environments by providing sophisticated and programmable centers for managing sensors, air conditioning and circulation, energy, water, and waste management, and other activities at relatively low costs.

Specific innovations in clothing and camping equipment are more difficult to identify. Several respondents pointed to improvements in technology in the 1950s and 1960s that led to (a) much improved and much less expensive protective clothing for mountain (i.e., cold and wet) environments, (b) lighter weight backpacks and camping equipment, and (c) such specific items as lightweight, dehydrated foodstuffs. Many of these innovations evolved from technology developed for the space program or for the military; it is reasonable to assume that similar technology transfer occurring during the next 20 years will make camping and hiking in the desert more comfortable (or at least safer).

Although incremental improvements in clothing and equipment will certainly appear as manufacturers and retailers note growing demand for this sort of desert recreation, really substantial innovation probably awaits the invention of "stillsuits," or individual moisture recycling systems. Many respondents note the desirability and, surprisingly, the likelihood, of the "stillsuit" concept for desert survival and recreation--an idea that was originally discussed in a science fiction novel, Dune (Herbert, 1965). Other developments expected in desert camping equipment and clothing include:

- "Solarization" of much equipment. Examples include solar water stills and solar photovoltaic cells for powering emergency communications equipment.
- Lightweight and inexpensive radio communications equipment will continue to improve and become ordinary equipment for many campers.
- Clothing that reflects much of the desert heat will become widely available at relatively low prices.
- Food capsules, characterized by less weight, may have slight effect on camping activities.

Recreation Management

The computer and parallel developments in sensing, communications, and microprocessor technology can be expected to play a major role in

managing recreation environments like the desert. Part of the difficulty in forecasting future uses of information technology in this area is uncertainty about software development. Much of the technology needed for relatively sophisticated management is already available or will be within the next 5 years. Deciding on its appropriate uses for recreation management and then developing the necessary and probably sophisticated programs have not yet taken place.

Combinations of these technologies are likely to provide:

- Sensors used to indicate noise, air, or water pollution in some park areas.
- Sensors used to indicate vehicles trespassing in areas restricted to foot traffic.
- Satellite sensing to indicate the presence of campers or vehicles, forest fires, and other occurrences in areas unattended by park personnel.
- Computers used for scheduling, reservations, modeling park use, management of park resources, and other management activities.
- Widespread dissemination of information about recreation facilities and natural environments to the public (i.e., information retrieval systems).
- Remote viewing via video of natural resources, protected flora and fauna, and other areas in which people are not allowed.
- Information systems for educational purposes on nature walks and similar activities.
- Portable video equipment that partly replaces photography as a recreational activity.

Some communications technologies may eventually compete with desert recreation environments, with many persons possibly replacing outdoor recreation with recreation at home. Few authorities think that such a development is likely within the next 20 years.

Other Technology and Other Factors

The single area of technology that could bring about profound and unanticipated change in recreational use of the desert is increased availability of water. A breakthrough in water desalination that reduces price sharply or lowers energy intensivity could provide the desert area with large amounts of now unavailable water. If such an event takes place, plans for creating large, artificial lakes would probably gain in acceptance. The long lead times associated with this breakthrough and lake construction would allow concerned agencies sufficient advance warning to make impact assessments easier.

Education and research in the desert are considered by some to be recreational activities. Technologies associated with both activities can be expected to increase their role in desert recreation. However, competition with other recreational activities will increasingly become a major issue. Areas of education and research in the desert include: zoology, botany, paleontology, biology, geology, ecology, plant taxonomy, herpetology, ornithology, entomology, and mammalogy (Stebbins et al., 1977).

Other factors, again only indirectly related to technology, should be noted as potentially influencing recreational patterns in the desert.

- Technologies that make easier living and working in the desert area indirectly influence demand for recreation by helping the shift of population to rural, desert areas. Thus, advances in energy production and use, in water recovery and transportation, in building design, in agriculture, and so on will have some indirect impacts on recreation.
- Accessibility to desert recreation areas is, of course, a key factor. Improved transportation systems between the CDCA and major Southern California cities, additional high-speed ground transportation between Los Angeles and Las Vegas, and additional roads and other transportation facilities in and through the desert are all possible before the year 2000. However, political and institutional factors will be more important (than technology) in determining whether such systems are built.
- An important response to technology that induces recreational damage (and, in some cases, simply excess demand) has been the growing regulation of recreation, especially for environmental protection reasons. Federal, state, and county agencies are involved in channeling recreation into desirable areas and away from those that are not (e.g., the establishment of ORV parks in many California areas).
- Competition among different recreational activities (e.g., between gyrocopters and motorcycles at El Mirage Dry Lake in San Bernardino County) sometimes creates safety hazards as well as congestion. Similarly, competition is growing between more traditional recreational activities (especially vehicular) and educational and research uses of certain desert sites, with proponents for the latter arguing for complete separation of activities in some cases (Stebbins, Papenfuss, and Amamoto, 1977).
- Changing values in regard to recreation will continue to influence choices about technologies that people employ in pursuing recreation. Distinctly different attitudes toward recreation, for example, may characterize groups that use high-powered, expensive ORVs and groups who prefer solitary or small-group camping and hiking. (Obviously, some people do both; nonetheless, each kind of activity reflects a different attitude toward recreational environments.)

- Increasing government management of desert recreation is likely to lead to the creation of additional national and state parks and monuments. New parks will rechannel existing recreation activities and will probably lead to growth in demand in adjacent areas.

- On the whole, the average age of population that uses the CDCA for recreation will increase during the next 20 years, with different priorities for outdoor recreation as a result. At the same time, increasing affluence for the same group will mean that more expensive recreation equipment can be afforded. The potential growth of minority populations in the area served by the CDCA may mean that different cultural values in regard to recreation and recreation technology will become more important.

- Increasing saturation, or at least congestion, at recreational facilities in the nearby metropolitan areas of Los Angeles and San Diego will increase demand for recreational use of the CDCA. For example, as urban densities increase, recreational general aviation and ORV use can be expected to more toward desert areas.

- Continued growth of an environmental ethic may result in its institutionalization with profound implications for directing how people can use the desert and how public agencies will allocate and regulate use.

- Increasing stress, complexity, pollution, and noise in urban environments can contribute towards making the desert area an increasingly attractive place "to get away from it all."

- For some people, the desert has a mystical or spiritual significance and represents a place of retreat, at least as long as such retreats remain isolated from other people and activities.

- Innovations in the workplace like job sharing, flextime, and the 4-day work week may increase leisure time, or at least blocks of time, thereby allowing people to go farther away from their homes for recreation. Some of them will go to the desert area, especially if it offers less congestion in recreational activities.

- Finally, Americans' liking for freedom of movement will be important to future use of the desert's open space for recreation.

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VII MATERIALS TECHNOLOGIES

Introduction

The desert contains a rich variety and significant quantities of hard rock minerals. However, minerals are not exploited just because they are available. The need for a mineral that would cause its exploitation in a particular location is complexly linked to its application in a product. Closing this linkage occurs when a designer specifies a certain material for a given application.

The impact of materials exploitation on the land use of the California Desert will stem from the demand for those materials stimulated by new or expanding technologies. The following discussion thus focuses first on those technologies that will require materials found in the desert, and then proceeds to the materials themselves. To understand the connection, one must first understand a technology designer's objectives.

Design Objectives in the Use of Materials

The designer is faced with certain problems or design objectives. If we assume that the performance of the product is fixed, at least in terms of its function, then the designer faces the following set of interacting objectives:

- Lower engineering and manufacturing costs. A product's first cost should be lower than the cost of the product it replaces or that which the competition can produce. If it is a new product, the production cost should be low enough to attract a market.
- Externally imposed product or process requirements. These range from product liability and consumer concerns to occupational health and safety and environmental considerations. Industry, customer, and government imposed performance standards are included.
- Material and component availability. If there is a new material on the market that satisfactorily meets a designer's objectives, and which is in good supply, the production and marketing branches of his organization may agree to specify its use.
- Lower operating costs. Cost savings include such diverse factors as simple operation and maintenance, to energy conserving design. With cheap energy, the trade-off favors reduce first cost. With more expensive energy, the life-cycle cost, including

operating cost, becomes more important. System use also becomes important. Accordingly, returnable beverage bottles cut system energy consumption, but the exchange required also inconveniences customers.

Design Solutions

The designer has several solutions that may solve one or more of the design problems and that may present trade-offs. These must be taken into account:

- Substitute materials and components for existing ones
- Design products that can be built more easily and economically
- Standardize materials and components
- Increase reliability
- Reduce or simplify maintenance
- Extend product life
- Reduce product energy requirement.

Materials Supply and Demand

In the supply and demand model used here the designer selects materials off the shelf to match the set of solutions that he chooses. The unanswered question in this model is how the material initially reaches the shelf.

Materials development may be application-specific, functionally specific, or both. It may begin with the obvious need to create a battery for automotive use whose performance is better than the lead-acid battery. Or it may be an attempt to develop materials that are corrosion resistant, of lighter weight, of higher tensile strength, and so forth. Accordingly, there are two categories of materials development:

- Applications driven--the end use and materials specifications are known.
- Technology driven--the end uses are generally unknown or only known functionally.

Thus, when we attempt to predict the future development of materials resources in a region, two questions must be answered:

- What are the expected technological developments in terms of applications that would require materials development?
- What are the expected developments in materials technology?

Whether California desert mineral deposits will be developed will depend on answers to the questions above, and on the relative economics and availability of alternative sources. For example, Alaska, though little explored, is known to have major deposits of lead, zinc, copper, molybdenum, gold, silver, and asbestos. Much of this resource may be made unavailable for exploitation by proposed legislation that would resolve Section 17(d)2 of the Alaskan Native Claims Act. Under H.R. 39, some 116 million acres (181,000 square miles) in new and existing park, refuge, and national forest lands would immediately be classified for management as wilderness and free of all forms of development. This legislation would also preclude exploration, and thus the mineral values foregone might never be known.

The California desert region contains a wide array of mineral deposits, some of which have been or are being developed. These resources are used in certain applications whose expansion can be projected as a function of population growth or external forces. For example, demand for borates in glass products has been rising sharply in recent years because of the increased use of glass wool for insulation. An alternative to this existing technology is plastic foam insulation. Solar heating and cooling, particularly some of the passive forms, may very well influence demand for insulation of dwellings.

Technology of Energy Conservation

The growth technology in the next 20 years may be energy conservation; this might portend a return to simpler technologies in which things are massive, have few parts, and are ruggedly built, reliable, and long lasting. The technology of conservation, however, is one that involves high technology and complex trade-offs among design objectives. The cost of operations (i.e., energy) is counted heavily against the cost of materials. The cost of built in malfunction diagnostics is factored into the cost of repair, another component of life-cycle costing. Computer control can optimize the functions of a complex machine like an automobile much better than can the human operator. It may no longer make sense for a driver to shift gears when the fuel mixture and ignition timing are controlled by computers to optimize combustion characteristics for maximum performance. With catalytic or conceivably laser-induced chemical reactions control of emissions, constraints on maximum performance may be reduced.

Conservation optimized technologies may have implications for:

- Manufacturing methods--In choosing manufacturing methods the energy cost of materials, components, and assembly methods will be explicitly considered. Energy-consuming operations will be carefully controlled by automation, and low-energy methods of welding and fastening will be used. Chemical processes will become more sophisticated, by employing catalysts and laser induced reactions, rather than temperature and pressure. More concern will be devoted to preventing heat loss by insulation and recuperation.

- Mechanical systems and components--Systems will be developed that are characterized by less noise and more efficiency. More efficient and longer lasting lubricants will be used, and elastomers will be employed to absorb shock, abate vibration, and correct misalignment. In the long run, transmission of power by electrical and fluid means will prove, with computer control, to be more efficient and quieter than mechanical systems.
- Plastics and elastomers--The technology for these materials is well developed. Incremental advances in structural plastics will occur to allow more substitution of plastics for metal parts.
- Solid-state devices--Incremental improvement will occur in the technology of rectifiers, diodes, and transistors, with the most improvement in integrated circuit technology. These devices will find increasing application in controlling, regulating, and diagnosing system operating conditions.
- High strength metals--Incremental improvement will continue in the technology; applications will increase for these materials because overall weight saving is sought be designers.
- Computers (used for design analysis)--virtually all design will be computer-assisted because complex trade-offs are sought between conflicting design objectives.
- Fluid power/fluid handling systems and components--Major improvements will result from the application of microprocessor computers for system control.
- Composite materials--The entire range of technology from ferro cement to boron and carbon epoxy compounds will be developed and find widespread application as designers seek lighter, more energy-efficient, and more easily fabricated materials. When burned, however, carbon epoxy compounds release carbon filaments that are electrically conductive and that in high concentrations, can make electrical circuits fail. This problem may require regulation of disposal of this composite material. Some composite materials, such as asbestos cement (transite pipe), might be a source of asbestos fibers that can be ingested by humans. In spite of these and other environmental problems, this class of materials will find increasing application.
- Microprocessors and computers used as product components--These technologies are grouped together because the former makes possible many applications of the latter. The technology will allow built-in diagnoses of component and system performance. Machines will no longer be limited by the capabilities that can be built into them or the skill provided by the operator, rather, through external programming or experience in memory, they will be able to improve and expand their functions.
- Opto-electronics, fiber optics--Because of their efficiency, simplicity, and flexibility, fiber optics will find increasing application for transmitting information in relatively small systems. They will be combined with microprocessor-computer and

light-emitting and light-sensitive semiconductors to transmit input sensor signals and output commands. Because of their relatively high transmission capacity, compared with wires, fiber optics will be used in crowded telecommunications systems, such as the telephone system in large central city areas. Opto-electronic technology will provide more efficient lighting as a direct plug-in replacement for incandescent lamps.

- New power sources--An economy seeking to conserve resources urgently needs more efficient means of converting heat to electricity and storing it in a lightweight readily available form. Thermodynamic cycles are basically limited if the materials involved cannot withstand high temperature. Only incremental improvements in high temperature power cycles will occur. Intense interest in magnetohydrodynamic generation will produce theoretical break-throughs by the end of the century, but few large-scale generating plants will be constructed. The scale of the basic operating unit that uses the mature technology will greatly influence its application. Will it necessarily be applied in 1000-MW units as are nuclear plants, or will it be developed for application through smaller units? Because of the institutional structure of the electrical power generating industry, research will be directed at the large units.

- Cogeneration--Provision by the electrical power generator of waste heat to a user such as a chemical plant, will increase in a conservation economy. The opportunities for such arrangements will be limited, however, and the institutional and regulatory structure of the electrical power industry is not correctly geared to this type of cooperation.

There will be no hydrogen economy based on coal; electric power generators and coal gasification and liquefaction plants will compete for the available coal. Because much of the coal reserves are owned by energy companies, they will be directed into profitable activities like synthetic hydrocarbon production for chemical feedstocks. By the end of the century, however, only a few synthetic hydrocarbon plants will have been built.

Breakthroughs in electric battery technology will make the electric automobile technically and economically feasible, at least for most urban driving. These breakthroughs will find the nation's institutions unprepared for the implications of a massive shift to electric automobiles. Although magnetohydrodynamic generating technology will come along in time to support such a shift, a massive debate conducted among the electric power utilities, the oil companies (who control the coal resources), and the federal government will delay it. Accordingly, the automobile companies will not make the investment necessary to supply electric automobiles on a large scale until after the turn of the century. However, those countries that have developed a nuclear electric economy, such as France and Japan, will exploit electric automobile technology.

- Lasers--Of the many things that lasers can accomplish easily and efficiently, the most significant will be laser chemistry. By the end of the century, laser chemistry will have started a revolution in the industrial chemicals field. Most modern chemical processes use conditions of temperature and pressure much in excess of those theoretically required for the specific reaction. Theoretically, lasers can excite the specific part of the molecule whose execution is required to make the reaction occur, thereby achieving great savings in operating energy and plant materials. The implications of lasers for simplifying coal conversion to synthetic liquid fuels will spur the controversy generated by the electric automobile. Laser-excited nuclear transmutation of dangerous radioactive by-products into radioactively benign products will renew the debate that has all but shut down the nuclear industry in the United States.
- Fluid logic--This technology will be incorporated in some compatible systems, but it will be surpassed in most applications by microprocessor-based computers.

This view of the technologies of conservation does not imply much for the minerals of the California Desert. Demand for minerals found in the desert may change dramatically as new technologies are developed. The following presents an overview of events that may affect minerals currently found in the desert.

Antimony and lithium are relatively scarce and little used at the present time, but rapid increases in demand could occur in the future due to new technological uses in batteries, other energy storage systems, fusion power systems, and electronic and electrooptic materials. A gradual increase in consumption over the next ten years could be followed by a spurt in demand at some time between 1990 and 2020. Lithium will become increasingly important based on brine deposits. Antimony may become important if significant discoveries are made. Also, natural zeolite deposits may become important in the future.

The Molycorp deposit of rare earth minerals at Mountain Pass is the world's largest supplier of light rare earths and only one of two large bastnasite deposits in the world. The other one is located in Africa. There is a great deal of research being conducted on rare earth metals and compounds, so there is a potential for a large increase in their use during the next 30 years. A major expanding use already is for sulfur removing agents in steels. Also, europium is critical for intense red in color television sets.

Copper, lithium, molybdenum, and silver are not expected to decline in importance in the absolute sence. They are not of great importance in the California desert at the present time, but would become so if significant discoveries are made and exploited. As an example, a huge deposit of medium grade silver is available near Calico, but cannot be exploited with present processing technology. A breakthrough in processing technology for the particular mineral assemblage containing the silver could lead to development of what would probably be the largest silver mine in the world.

Other minerals could become important if significant discoveries are made. There are reasonably good chances for discovery of large porphyry deposits (Cu and Cu-Mo) in the California desert based on geology similar to that found in Arizona and other Rocky Mountain states (Basin and Range Province), and there have been some isolated small discoveries of uranium. It is the tendency in uranium exploration to continue drilling in areas of known commercial uranium concentration. There has been little exploration work below the surface for any mineral where surface outcrops do not occur in the California desert. Since uranium is widely distributed, it is likely that commercial concentrations could be found in the California desert if there were sufficient exploration incentive, and this will occur over the next 50 years.

Beyond extrapolating from existing demands for materials from the California desert region, there appears to be no basis in anticipated future technological developments for responsible speculation about increased or new demands. Large uncertainties exist about the time in which materials will be required (as well as their quantities) by the technological developments discussed above. Even if these demands should develop as anticipated, there is further uncertainty regarding the economics of supply from California, compared to other sources. The California desert may be "well explored" when compared with other locations, but land-use policy should not foreclose exploration and development until the desert's mineral potential has been well established. Even if the potential, once established, is judged to be uneconomical, based on the quality of the ore or the existing demand for the mineral, land-use planning should allow for future contingencies when technological developments may affect both the supply and demand of minerals. Although land-use decisions can be made that would withdraw land from mineral development, they should, if possible, not be made irreversibly, and they should provide for exploration if mineral values have not been well established.

In addition to the minerals extraction potential of the California desert is its potential to provide waste disposal sites. Future environmental regulations will increasingly restrict emissions into air and water. More wastes will end up in liquid and solid form, and such technologies as laser chemistry may make recycling technically and economically feasible. The California desert is adjacent to a large metropolitan area which will generate large amounts of liquid and solid waste, even in an energy conservation economy. As adequate nearby waste disposal sites are filled, the desert will be examined as a site. Modern landfill operations can be safely spread on certain desert formations if precautions are taken to prevent contaminating the groundwater and leaching by flood waters.

The relative impacts of the various technologies discussed above are summarized in Table 7.

Table 7

CONSEQUENCES OF FUTURE TECHNOLOGY MATERIAL REQUIREMENTS FOR THE CALIFORNIA DESERT

Technology	Likely Consequences for California Desert Region	Potential Consequences
Manufacturing methods	Indirect through use of other technologies requiring materials such as catalysts, lasers, solid-state devices, microprocessor computers, and opto-electronic-fiber optics. Indirect through use of synthetic greases. Replacement of mechanical drives with fluid power and electrical power devices.	Moderate
Mechanical systems and components	Indirect through use of synthetic greases. Replacement of mechanical drives with fluid power and electrical power devices.	Small
Plastics and elastomers	Indirect through increased use of structural plastics, especially composites.	See composite materials below
Solid-state devices	Direct through use of precious metals and rare earths.	Moderate
Computers (in design analysis)	Indirect in making trade-offs for design for energy efficiency.	Large
Fluid power/fluid handling systems and components	Indirect through use of solid-state devices, opto-electronics-fiber optics, and micro-processor computers.	Moderate
Composite materials	Direct through use of boron and glass fibers in composite materials.	Large
Microprocessor-computers	Direct through use of precious metals and rare earths.	Moderate
Opto-electronics, fiber optics	Direct through use of glasses, solid-state devices, and phosphors.	Large

Table 7 (Concluded)

Technology	Likely Consequences for California Desert Region	Potential Consequences
New power sources	Direct through use of materials for more efficient batteries, indirect through use of solid state devices, opto-electronics, and microprocessor-computers in control devices.	Large
Lasers	Direct through use of materials for laser devices.	Moderate
Fluid logic	Direct through use of glass materials for logic devices.	Small
Waste disposal	Direct through use of certain features such as dry lakes.	Large

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VIII SPACE AND COMMUNICATIONS

Introduction

NASA is changing its institutional attitude. Gradually, more thought will go into establishing experimental objectives to order the priority of the value and utility of the knowledge to be gained rather than a "hardware first" approach. Those agencies whose missions and responsibilities can be facilitated by space operations therefore can define their needs and design experiments to meet them. Much that will be accomplished is likely to be useful in desert planning and management.

In the near term, the space program will emphasize the observation of phenomena that occur on earth as well as in our solar system. The program will use space labs, unmanned special purpose satellites, and perhaps an orbiting space station. Communications will be greatly enhanced by the proliferation of communications satellites, but institutional problems with the agencies that allocate frequency bands and that regulate the telecommunications systems may occur.

Remote Sensing

Sensors in spacecraft can measure electromagnetic radiations given off by emitting surfaces. They can also measure magnetic and gravitational force fields. However, the surface emanations or manifestations must be interpreted to arrive at subsurface occurrences. Whether a technology will develop that will allow remote sensing to sense such subsurface characteristics constitutes an important question.

Magnetic and gravitational anomalies have long been used in mineral prospecting to locate ore bodies; aircraft carrying sensitive detectors can cover a large area in a short time, and acoustical reflections from either natural or, more usually, manmade detonations have also been employed in studying subsurface geologic structures. Acoustical reflections are used to detect submarines below the surface of the sea (as are magnetic and gravitational anomalies). Sensors mounted on aircraft and spacecraft form a continuum, ranging from detailed but highly focused sensing from low flying aircraft, through high flying aircraft (~100,000 feet), to orbiting and geosynchronous satellites that can capture a synoptic image.

Strictly speaking, all the sensors detect phenomena as signals emanating from the surface of the earth, even though they may be subsurface in origin and may be changed by interacting with the intervening atmosphere. In some cases, it is possible to combine sensing with man-induced

subsurface phenomena (e.g., sonobuoys). In other cases, signals may be sent from the platform and reflections picked up by the platform-mounted sensors, (e.g., radar and laser interferometry).

Remote sensing technology will advance in combination with surface-mounted stations emitting signals (e.g., sonic or seismic) that penetrate the subsurface matter and are reflected to be detected by surface stations. The surface stations can be interrogated periodically by the satellite, or the reflections can be detected directly by the satellite. Spacecraft will also become larger and develop more power; they may be able to beam penetrating rays to interact with subsurface material and to be reflected for detection by sensors on spacecraft. However, beamed and reflected energy must be innocuous to man and other life forms, and this will not be possible before the end of the century, if at all. Development of solar energy collecting spacecraft depends on making the microwave beam by which energy is transmitted to earth spatially stable within relatively narrow limits.

Advanced satellite sensing, combined with sophisticated interpretation and accurate and relatively dense data that indicate the situation on the ground will thus be used in coordination with ground stations and will be the most important technological development for land use planning, management, and enforcement for the remainder of the century. Other platforms will measure incoming forms and amounts of energy and the planetary force fields, and space probes will explore the solar system. The construction of their development will lend to a detailed understanding of relationships between terrestrial phenomena and events in the solar system. For example, hypotheses abound concerning the influence of solar activity on terrestrial phenomena such as the weather, as well as on the influence of solar system planetary configurations on terrestrial gravity forces and related phenomena such as tectonic activity.

Communications

Increasing sophistication and use of communications satellites will remove one constraint to increased activity in the desert region. By the year 2000, instant, reliable communications between any point in the desert and any point in the world may be possible. This communications potential will provide for high-speed data transmission. Satellites will also distribute television and radio programs. Whether or not the scale of local operations will render the system economical to local users will depend on how many users have to share the cost of a local transceiver and antenna system. Whatever the number (which will be large at first and decrease as technology improves), the local land links can be by radio, such as citizens band, or by cable, such as for television.

Some current policies must be revised before the communication systems become a reality. These systems will most likely be essentially private telephonic systems in competition with the existing telephone companies. The new systems will initially serve large corporations or government agencies requiring high-capacity data transfer systems; once

established, however, they will have spinoff capacity for serving isolated customers. As with any wireless communication link having many potential users, allocating the radio spectrum is a problem. This problem can be overcome to some extent by more directional broadcasting to minimize interference with other broadcasters. A more difficult sociopolitical problem is in chartering services brought about by technological advances that will compete with an existing, regulated monopoly. Regardless of how this issue is resolved, on a legislative or judicial basis, the advances in technology will be applied. Whatever the merits of competition versus monopoly, a technology will advance faster as a competitor of an existing system.

Navigation

The implications of reconnaissance satellites for military activities in the desert are addressed in the following section. Navigation by satellite has been restricted to military use but could have broader applications. These electronic beacons provide known reference points by which an aircraft or naval vessel's position can be accurately fixed. The system will probably spread first to commercial and private aircraft before it is used for land-based and inertial navigation systems. With progress in microprocessors and large integrated circuit chips, suitable receiver-computers will become available for on- and off-road vehicles and even for hikers. The combination of this navigational certainty with radio reception from a broadcasting satellite could provide the measure of security whose lack currently prevents many from venturing onto the desert.

Space Lab

The first four space shuttle missions will use Edwards Air Force Base as their landing site. After that, Edwards will be used only as an alternate if for some reason the primary landing site is not available. For these first landings, many tens of thousands of visitors can be expected. The spacecraft will return supersonically in a direction that is perpendicular to the Edwards supersonic corridor. However, these are temporary consequences. More lasting consequences for the desert may arise from the experiments that are conducted on board the space lab pallets. Some will involve extraterrestrial phenomena; others will advance the technology of earth resources sensing. Still others will use the nearly perfect vacuum and weightlessness of an earth orbit to study material characteristics and processing--materials that the desert may supply.

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IX TECHNOLOGY AND MILITARY USES OF THE DESERT

Introduction

The military uses the California desert because it provides:

- Large areas of relatively uninhabited space
- Isolation from activities that interfere with military business
- Terrain features not found elsewhere (e.g., dry lakes)
- An environment similar to other deserts in the world in which military operations might be carried out
- Climate and weather characteristics ideal for activities like flying.

The principal features of the desert environment--space and isolation--are rapidly being compromised. The airspace over the California desert is already crowded, and traffic is expected to increase. Should Los Angeles open a jetport at Palmdale, traffic will increase. Military installations are increasingly having problems with encroachment by the communities that have grown up around them, primarily to support their activities, and are encountering increasing numbers of trespassers in off-road recreational vehicles. More people are stopping at potentially dangerous locations on the periphery of military reservations in self-contained recreational vehicles.

Security and Strategy

More importantly, perhaps, military activities in the California Desert are being surveilled by sophisticated electromagnetic emanation sensors of off-coast Russian trawlers and overhead orbiting spy satellites. Surveillance has three implications for the testing of advanced military devices in the California Desert:

- Some of these activities may move inland to increase security (e.g., to White Sands Missile Test Range in New Mexico).
- Some activities in the California Desert may be mounted to deceive and mislead unfriendly surveillance.
- Some testing will become more sophisticated and more subtle, using simulation in some aspects.

Advances in reconnaisance have interesting implications for maintaining a balance of power between major adversaries. During the early arms limitations talks, mutual inspection was a key element. Now satellite inspection is completely at the discretion of the inspector. The undetected launching of a first strike is thus highly improbable. The response is to develop antisatellite weapons and a stronger dependence on high technology conventional forces. Actually employing antisatellite forces would be an almost sure indication that a first strike is intended and might even stimulate a preemptive strike.

Conventional forces are becoming increasingly expensive as weapons achieve greater technological sophistication. At the same time, international diplomacy is emphasizing the extension of a nation's sphere of influence by fear or by friendship. A huge arms industry has grown as the western nations compete to supply weaponry to each other and to the growing numbers of friendly or unaligned nations that feel the need for state-of-the-art military capability and have the resources to buy it. The arms sale creates a temporary dependency of the buying nation on that supplying the weapons.

Modern weapons systems are so complex that a technologically emerging nation may require years of support and training before it can support them internally. This technological dependence creates tolerably friendly relationships if not an ideological dependency. Out of all this there develops an arms race of sorts. Testing and development of weapons will be accompanied by intelligence gathering, to verify that a nation's armaments are superior to the potential adversary's, as well as to those of competing friendly nations. Thus, purposeful deception of the opposing nation's intelligence apparatus could be an alternative for those nations that are not in the international weapons market.

Sales are based on intelligence showing that a potential adversary is ahead in the state of the art. The implications for the California Desert are that the United States, as an arms exporter, will develop and test advanced technology weapons systems, even if they are too expensive for the United States itself to purchase in large numbers (e.g., the B-1 bomber). The SALT II talks have therefore had to address technology development as well as the numbers of weapons of various kinds deployed by each nation.

Weapons Technology and the California Desert

Will testing and development of advanced technology weapons systems on the California desert produce different effects from that currently conducted? In the final analysis, most weapon systems involve a projectile impacting on or near a target. The only new technology that deviates from this somewhat comprises directed energy weapons, especially lasers, and particle beams, that deposit energy on or within a target. All other activities connected with weapons systems facilitate or prevent the interaction of a projectile (warhead) with a target. Testing does not usually, but can, involve an explosive warhead. Testing must thus focus on the delivery system, which includes the launcher, the target, and the

missile. Thus weapon systems are classified as surface-to-surface, surface-to-air, air-to-air, and air-to-surface systems. The missile can be aimed, guided, or programmed. It can be ejected with sufficient kinetic or potential energy to reach the target, or it can be self-propelled. The most significant developments will be in short-range directed and programmed, and long-range programmed missiles. The former are for tactical use and the latter are strategic weapons.

There are several tactical and strategic missile concepts under development that lower weight and cost and increase speed and reliability. Trade-offs are being sought, for example, between accuracy and expense. Advanced sensor concepts that provide "fire and forget," night and all-weather capabilities, and electronic countermeasures are being developed. The strategic course missile concept is being developed to provide maximum commonality between several aspects of the Navy and Air Force operations, which will all require component and system testing. As the missile arsenal grows and as the concepts become more specific, the testing requirements will increase.

The nature of the testing will be similar to that conducted now, although some of the test range capabilities seriously need updating. The improved speed and range capabilities may require more buffer land around the test regions that is zoned to prevent development and encroachment. The California Desert is not expected to play a significant role in strategic missile testing or deployment, although some development of the cruise missile and its components will take place there. The desert offers a necessary characteristic for directed energy weapon testing only in one case. Should the Naval Weapons Center be successful in developing a significant geothermal energy source at Coso Hot Springs that is devoted to Navy use, it could provide a power source for high energy beam testing.

Aircraft Testing

The California Desert is also the location of aircraft testing and training which will continue with a higher percentage of supersonic runs. Remotely piloted and programmed vehicles will find more applications in the future. These vehicles will comprise an increasing fraction of the test flying and will present some unique air safety problems in the increasingly crowded air space. The Naval Weapons Center has devised an air space management system designed to minimize some air space problems.

Desert Warfare

In the past the California Desert has been the testing and training ground for desert warfare tactics and forces. It is said that some of the tracks from General Patton's training maneuvers in preparation for the World War II invasion of North Africa can still be seen. As long as the situation in the Middle East remains tense, U.S. forces will undoubtedly keep ready for desert warfare. Much has been learned about desert conditions from fighting in the Sinai, and this knowledge is

available to U.S. military experts. Desert warfare is now highly mobile, fast-moving, involves relatively few forces, and is quickly settled. A small force of desert-trained armored forces will be maintained and will maneuver in the desert environment periodically with combined air forces. Other armored infantry troops will have experience with advanced versions of antitank and antiaircraft missiles that proved so effective in the Sinai, but need not necessarily have desert experience. If these desert troops are to be effective in the kinds of situations expected in the Middle East, they must have air lift capability for themselves and their equipment. However, a Middle East settlement now appears more feasible, and perhaps a stable realignment of the major powers in that part of the world will follow.

The Desert Garrison

Other military activities are based in the desert because of its convenience and climate. Tney will remain, but will not grow unless the defense budget forces consolidation of units. Bases in other parts of the country may face problems of encroachment by nearby communities; this encroachment may limit their activities but at the same time may minimize the impact of base closing. Therefore, consolidation would favor the desert bases. The desert bases themselves will be limited by the water supply and housing.

The Desert Psychology

At the tactical level, the important point is that the United States has recently experienced, directly or indirectly, two types of warfare that lead to military schizophrenia. The Viet-Nam war demonstrated that high technology and mobile forces could not win over a determined and dedicated low technology force in jungles, given constraints on military attacks on the enemy's homeland. On the other hand, the Yom Kippur war in the Middle East demonstrated that, in the desert environment, technology was very effective, losses were devastating on both sides, and the United States airlift to resupply Israeli forces made the difference. The war was settled by external intervention, but in any event it would not have lasted long. As an economically advanced nation, the United States relies on the technological imperative, despite the lessons of Viet-Nam.

Environmental and Land Use Consequences

The environmental and land use consequences of military activities in the desert must be viewed in the light of what this presence prevents as well as what it causes. Military activity, whether it is testing or training, induces growth, which in turn affects the ability of local communities to supply municipal services. In some cases the military has provided these services; federal aid is also made available to communities affected by the military presence. A typical pattern in a new area is for the military to establish living quarters and municipal services for dependents and civilian employees. As the installation grows, a town may spring up to provide goods and services to the military

and their dependents. As the town grows, it acquires political clout and forces the military to reduce some of the base-supplied, subsidized services. The military gives in on this issue and thereafter feels political pressure whenever the installation and the town encroach on each other's peace and activities. Most of the military installations in the California desert are in this last stage of town/base evolution. But a threat to close the base engenders an immediate appeal by the town fathers to higher authorities.

The vast acreages under military control in the California Desert are in a better environmental and ecological condition than if they had not been controlled. Most test and training activities do not use live ammunition. Military activities do leave behind junk and debris, including unexploded munitions, but they have kept other human activities out of the region. These relatively small areas of the reservation that receive heavy use are seriously affected, but large areas get little or no use. Because the United States has agreed to forego chemical and biological warfare, military activities introduce few, if any, refractory toxicants into the environment. Land use planning of the desert region should recognize the positive environmental value of military installations and include buffer zones around them. Within these zones, neither military nor civilian activities would be expected to encroach, but even if penetration occurred occasionally and by accident, there would be little consequence. The military for their part might regularly police the areas for accumulation of residual equipment, and open portions of their real estate and facilities for civilian activity under close supervision. A real difficulty in military situations is enforcing the division to dedicate a large area of remote land to a particular purpose. Although the military is under heavy budget pressures, they possess the technology and are better able to marshall forces to enforce such a decision.

X TRANSPORTATION TECHNOLOGY

Introduction

Despite prospects for considerable technical innovation, the transportation sector is unlikely to undergo major technological innovation within the next 20 years. No technological element of any major transportation mode is likely to have a major impact on the desert area before 2000. Rather, increased demand for transportation services in, through, and over the desert area, and concomitant demand for new or extended facilities are likely to be the major causes of impacts.

Changes in transportation technology will only indirectly influence demand. Innovation over the next two decades will primarily focus on improving efficiency by reducing unit costs. Automobiles and trucks, for example, will become increasingly more energy-efficient, as will most other modes for which energy represents a major fraction of operating cost. Similarly, most freight and some passenger carriers will become larger; trucks, railroad cars, and aircraft can be expected to grow in size and carrying capacity. These factors, however, will have only minor impacts if any at all.

From the perspective of potential impact, the following developments--only indirectly related to technological factors--are expected to be most important to the desert area:

- Growing traffic at metropolitan Los Angeles airports will increase pressures to open a second major facility for Los Angeles at Palmdale, California, where an Air Force facility is now located. Were Los Angeles to become a terminus for SST travel, the Palmdale site will become even more important.
- With increasing congestion at major metropolitan airports, general aviation (especially nonbusiness) will shift toward less crowded, rural facilities; in this case, in the desert area.
- Railroad and truck freight traffic can be expected to increase steadily on the present major routes through the desert area; before 2000, it is unlikely that major new highways or new railroads will be needed; existing facilities, however, will probably be expanded and improved.

Railroads

Few changes are expected in railroad technology during the next 20 years. If anything, rail cars will become larger; newer and safer track will replace old systems; and automation will play a major role in the handling of rail cars in yards. Much of this change has already taken place in Southern California. Three major (heavily used) railroads cross the desert, and two relatively new yards are located in Barstow and Colton; both employ highly advanced technology.

Although the three major rail systems compete, each is highly profitable in connecting Southern California with different parts of the United States. Where they go and the kinds of goods they carry are, of course, factors that will influence future demand.

(1) Northernmost is the major Union Pacific (UP) line from Chicago through Ogden, Utah; Las Vegas, Nevada; and Barstow, California, where it joins the major Santa Fe line. The UP line is a single track railroad that primarily carries trailers on flat cars (loaded with general merchandise) and coal trains to the Kaiser Steel facility at Fontana. Increasing demand for Utah coal will mean greater use of this line, thereby requiring construction of additional track. For the most part, impacts will be limited to construction and maintenance of facilities, although minor environmental impacts will occur from railroads carrying coal.

(2) The second major line is the two-track system of the Santa Fe (ATSF); it roughly follows Interstate 40 (formerly U.S. 66) through northern Arizona, New Mexico, and thence to Chicago. Trailers on flat cars, general merchandise, automobiles and automobile parts, and New Mexico coal are the main goods carried. Use of this track is expected to grow, especially for carrying coal from New Mexico to Southern California markets.

(3) The third major line, Southern Pacific (SP), follows a more southerly route from San Bernardino through the Coachella Valley, to Phoenix, Arizona, and thence to the Southeastern United States. A major branch of this line serves the Imperial Valley. Goods carried on the SP line are similar to the ATSF, except for coal. The SP currently uses a single track.

The three rail lines are well maintained, heavily used, and profitable.

The only major technological change that could take place during the next two decades is the electrification of one or more of these lines--east from Colton on the Southern Pacific or east from Barstow on the ATSF. However, electrification is expensive, essentially doubling their real holdings of these lines. The major environmental effects of

electrification would be incurred from construction activity and the visual impact of electrical wires strung from poles. The benefits could be derived from elimination of emissions from diesel engines. Because electrification of the railroads would involve many federal, state, and local agencies, considerable advance notice of electrification can be expected.

In the desert the ATSF and SP lines pass through Mojave to the Central Valley. Should there be a demand for coal in the Central Valley for power generation, greater traffic on these tracks can be expected.

Trucks

Innovation in truck technology usually occurs slowly. Although considerable innovation will, in fact, occur during the next two decades, most of it will be directed at improving the energy efficiency of trucks and will have little direct impact on trucking in desert areas. One consequence of higher energy prices, however, has been pressure to lengthen trucks and to increase their load capacity. In general, the Western states, including California, have been more liberal than the Southeast in allowing larger trucks. This trend is expected to continue, although eventually all state trucking regulations may become standard.

Larger trucks would require widening or strengthening of highways. Because this is generally an ongoing process on major routes, little impact on desert areas from changing truck technology is expected.

Pipelines

No new technological developments for pipelines are expected during the next 20 years. Several new pipelines may be built through the desert area during the period, but their construction will be affected more by economic and political factors than technological ones.

The economics of coal slurry pipelines are not yet well known. Experience in other parts of the United States may show them to be competitive with unit trains in deliveriny coal from Utah or New Mexico to Southern California. Given the relatively small demand for coal in the Los Angeles region, it is likely that through the year 2000 railroad transport will be most economical.

If an export market for coal develops in the Orient, then the volume of coal moved may make slurry pipelines competitive economically.

Other Ground Transportation

In general, changes in automotive technology will have little if any impact on the desert area. Air emission standards for automobiles will help reduce air pollution, although growing use of automobiles may outweigh the benefits of better control technology. Electric automobiles

are not expected to be a factor in most desert areas (except perhaps in some cities like Palm Springs) before the turn of the century, mainly because of their limited range.

Advanced high-speed ground transportation systems, although technically feasible, are unlikely to be built in the desert (or in most other places) in the next 20 years because they are too costly for present and expected needs. In general, complex and costly high technology systems take many years to build, and sufficient notice is required to study their potential impacts in detail.

Aviation

For aviation, as for the other modes, increased demand placed on existing facilities is the major issue rather than new aviation technology. However, several potential technological events could influence the location of such facilities in the desert and in adjacent areas. In particular, a successful supersonic transport would increase demand for a major metropolitan airport outside of Los Angeles. Less likely and with less certain impacts for the desert area would be the successful commercial development of VTOL/STOL* aircraft; in the main, VTOL/STOL would be able to use smaller airport facilities in the desert area.

Two major trends or issues in Southern California aviation that are only indirectly related to improvements in technology could have important impacts for the desert. The first is the possible construction of a second major airport for Los Angeles at Palmdale, California.

Proposals to use and extend existing Palmdale facilities have come and gone before. However, projection of demand to 2000 for Los Angeles International indicates that a second facility will be needed. Alternatives to the Los Angeles International airport are already overcrowded or inadequate for the kind of aircraft LAX serves. Eventually, some alternative will have to be chosen. Such development could result in:

- Land banking and zoning in the Palmdale airport area
- Air quality and noise environmental impacts
- Construction impacts
- Increased traffic on the State Highway 14 corridor and the possible need to construct a high-speed mass transit link to downtown Los Angeles.

A Palmdale facility or any other major alternative in the desert area will probably result in extensive political debate.

Second, the movement of nonbusiness general aviation into the desert will probably continue. Dongestion at major metropolitan airports has

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*Vertical takeoff and landing; short takeoff and landing.

forced a shift of business-oriented general aviation toward peripheral airports (e.g., Hollywood-Burbank); other general aviation has increasingly been forced away from even these facilities to rural airports. In addition, agricultural businesses are increasing their use of general aviation craft in the desert area. Although the rate of growth of aviation activity is expected to slow over the next 20 years, compared with the last 20, growth plus the potential shift of aviation toward the desert means substantially increased use of desert area facilities. Impacts, however, will probably be local and minor. General aviation groups may urge the expansion of desert area airport facilities.

Continuing improvements in landing control, navigation, flight control, and similar high technology systems are also important to aviation. From the standpoint of impact, however, these technologies will generally take up little space and have few employees. Some facilities will be located in the desert area, but minimal impact can be expected.

Summary

In general, transportation technological innovation will have little if any direct impact on development in the desert area over the next 20 years. Transportation will follow, rather than lead, economic development in the desert and adjacent areas.

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